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MILLING WITH A TOOL WITH UNEVENLY DISTRIBUTED CUTTING PLATES

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Abstract: *This article is to present the results of experimental research and the analysis of recorded signals of relative displacements in the tool-workpiece system during face milling with an endmill will 3 unevenly distributed cutting plates and 6 evenly distributed cutting plates. The measurement stand was prepared on a numerically controlled vertical milling center VMC 800 manufactured by AVIA, with the use of a laser interferometer system manufactured by Renishaw and a measurement track. The processing involved machining of samples made of C45 steel with the use of a CoroMill R245-080Q27-12M cutter with the diameter of Ø80 mm, manufactured by Sandvik Coromant. This article has presented the results of experimental research concerning the influence of asymmetrical and symmetrical distribution of plates in the tool body and the feed velocity on the value of relative displacements in the tool-workpiece system. The results have been presented in form of charts reflecting the relative displacements in the tool-workpiece system, depending on the time, FFT analysis charts (Błasiak, 2016), standard deviation of relative displacements, and feed on the cutting edge.*

Keywords: Vibrations, Shifts, End milling, Tools with uneven tooth pitch, Feed, FFT analysis.

1. Introduction

The process of end milling involves a machining tool, grip, tool, and the machined object, which together for a structural layout with dynamic characteristics. The process of milling is a machining process that results in formation of unwanted relative displacements (vibrations) of the component elements of the layout machining tool - grip - machined object - tool in that layout. Those vibrations are caused by forcible and kinetic interaction. Such displacements have a significant impact on the accuracy and the quality during the milling process of precision machine parts, i.e. seals (Blasiak and Zahorulko, 2016), pistons (Adamczak et al., 2015), (Ambrozik et al., 2014), pneumatic parts e.g. valves, muscles (Takosoglu, 2016), (Takosoglu et al., 2016). Displacements in the layout machining tool - grip - machined object - tool cause tool wear, release of heat (Bartoszuk and Grzesik, 2011), (Pastuszko, 2014), and noise emission during the process of machining (Nowakowski, Łukasz Mięsikowska and Błasiak, 2016), (Mięsikowska, 2016). A dynamic layout is formed by: a mass-dissipative-elastic system and working processes that are affected by forcing, controlling, and distorting signals. During the operation of the machining tool, there is the possibility of occurrence of three types of displacements (vibrations): free (own) movements, movements forced kinetically, and self-oscillations.

The displacements generated during the machining process in the tool-workpiece system constitute a great limitation in the suspension of performance of the milling process and they have a significant impact on the obtained geometrical structure of the machined surface (Miko, 2005), (Nowakowski and Wijas, 2016).

There are four basic factors that influence the formation of relative displacements in the tool-workpiece system during the milling process: the setting angle and the cutting force, the tool diameter and the radial depth of cut, geometry of the plate, the toot pitch of the tool. This article has described the research

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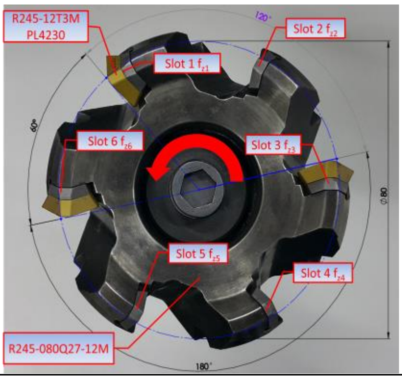
concerning the influence of the tooth pitch of the cutter on the relative displacements in the tool-workpiece system. One of the reasons for changing the tooth pitch of the tool during this research might have been caused by damage of the plates in the body of the tool.

2. Methods

The subject of the research was to record and analyze the signal of relative displacements in the tool-workpiece system during an end milling process with a simulated damage of 3 plates in the body of the tool, as well as without such damage.

Machining attempts were conducted at a vertical milling center AVIA VMC 800, where rectangular samples (dimensions of 30 x 70 x 50 mm) made of C45 steel were milled with a CoroMill R245-080Q27-12M tool; the length of the length of the tool movement was 70 mm. The cutter CoroMill R245-080Q27-12M has, as a standard, 6 symmetrically distributed plates every 60 ° sockets for cutting plates. During the attempts, an uneven distribution of R245-12T3M-PL4230 plates was achieved with enforcing the 1st, 3rd, and 6th socket. The uneven distribution of the cutting plates in the cutter disturbed the symmetry of the milling process by changing the feed on the tooth for sockets 3 and 6. For comparison purposes, machining attempts were also conducted with a tool facilitated with all 6 plates. The view of the cutter plate and the parameters of work of each plate have been presented in Tab. 1.

Tab. 1: View of the cutter plate and the parameters of work of each plate.



v_c = 205 m/min, a_p = 1 mm, z = 3								
f_z, mm/tooth								
0.1			0.15			0.2		
Slot 1	Slot 3	Slot 6	Slot 1	Slot 3	Slot 6	Slot 1	Slot 3	Slot 6
f_{z1}	f_{z3}	f_{z6}	f_{z1}	f_{z3}	f_{z6}	f_{z1}	f_{z3}	f_{z6}
0.1	0.2	0.3	0.15	0.3	0.45	0.2	0.4	0.6

The measurement of relative displacements during the machining attempts with various feed values were implemented on a patented working stand (Miko and Nowakowski, 2013) with a laser interferometer system manufactured by Renishaw and an accurate measurement track; the working stand was mounted on the machining tool VMC 800 manufactured by AVIA (Fig. 1).

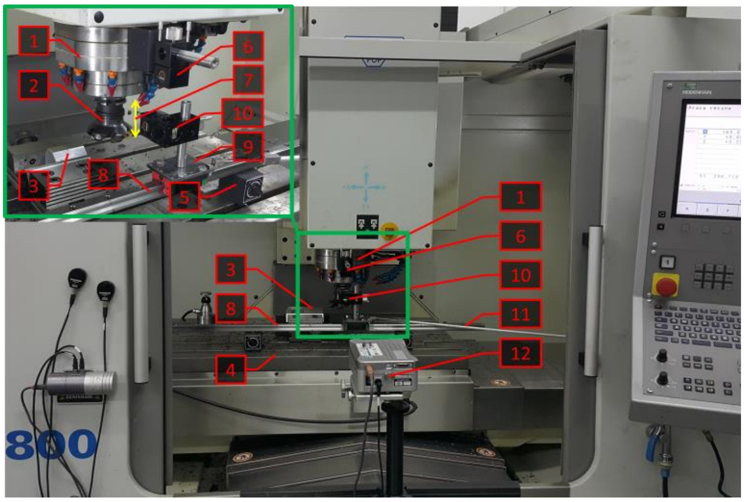


Fig. 1: Schematic of device for measuring displacements in the tool-workpiece system: 1- spindle, 2 - milling head, 3 - workpiece, 4 - table, 5 - magnetic base, 6 - linear reflector, 7 - vibrations in the tool-workpiece system, 8 - rail, 9 - block, 10 - linear interferometer, 11 - link, 12- XL 80 laser.

3. Results and conclusion

As a result of the conducted research, it was possible to determine the influence of velocity of feed on the tooth f_z and the uneven distribution of cutting plates in the body of the cutter on the peak-to-peak value and the standard deviation of the signal of relative displacements in the tool-workpiece system during the process of face milling. Fig. 2 has presented an example of a part of the signal reflecting the displacements in the tool-workpiece during the process of milling (Tab. 1, no. 1), for the measurement time of 1 s. Fig. 3 has presented the FFT analysis of the recorded signal of relative displacements for the feed of f_z = 0.1 mm/tooth.

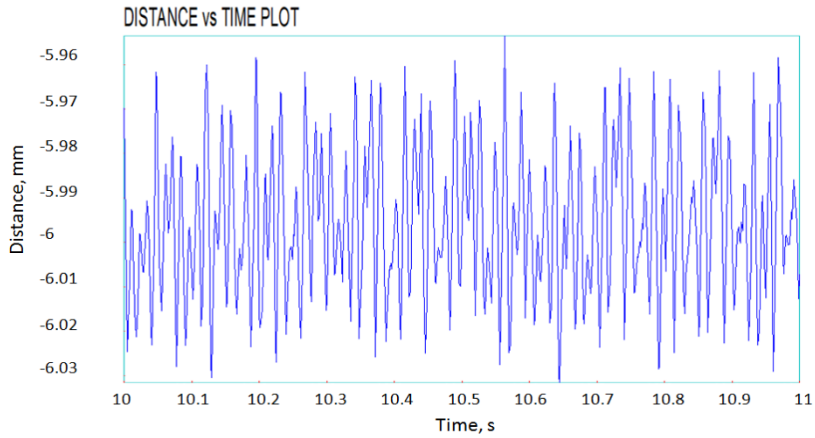


Fig. 2: Fragment of an unfiltered signal of relative displacements in the tool-workpiece for the milling process (v_c = 205 m/min, f_z = 0.1 mm/tooth, a_p = 1 mm, z = 3).

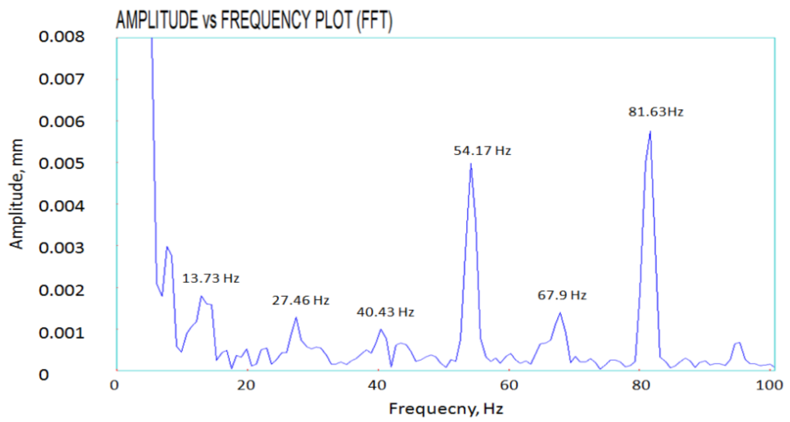


Fig. 3: The amplitude-frequency chart for the signal of relative relative displacements in the tool-workpiece for the milling process (v_c = 205 m/min, f_z = 0.1 mm/tooth, a_p = 1 mm, z = 3).

Tab. 2: The analysis of recorded signals of relative displacements in the tool-workpiece system.

<table>
<tr><th rowspan="2">Lp.</th><th colspan="4">Cutting parameters</th><th colspan="4">The results of signal analysis, µm</th></tr>
<tr><th>v_c, m/min</th><th>f_z, mm/tooth</th><th>a_p, mm</th><th>z, szt</th><th>Max</th><th>Min</th><th>Peak to peak</th><th>Standard deviation</th></tr>
<tr><td>1.</td><td rowspan="6">205</td><td>0.1</td><td rowspan="6">1</td><td rowspan="3">3</td><td>50.32</td><td>-44.17</td><td>94.49</td><td>16.38</td></tr>
<tr><td>2.</td><td>0.15</td><td>70</td><td>-56.89</td><td>126.89</td><td>22.98</td></tr>
<tr><td>3.</td><td>0.2</td><td>69.12</td><td>-56.84</td><td>125.89</td><td>24.72</td></tr>
<tr><td>4.</td><td>0.1</td><td rowspan="3">6</td><td>21.75</td><td>-14.61</td><td>36.36</td><td>7.41</td></tr>
<tr><td>5.</td><td>0.15</td><td>23.68</td><td>-16.55</td><td>40.23</td><td>8.2</td></tr>
<tr><td>6.</td><td>0.20</td><td>25.56</td><td>-17.65</td><td>43.21</td><td>8.83</td></tr>
</table>

During the analysis of the results presented in Tab. 2, it has been concluded that in both cases, when the cutter was facilitated with all plates and when only the 1st, 3rd, and the 6th socket were used, the increase of the feed caused an increase of the peak-to-peak value of the displacements signal and its standard deviation. Introduction of asymmetry in the distribution of cutting plates in the sockets of the cutter resulted in an increase of the value of relative displacements in the tool-workpiece system in relation to the cutter facilitated with all 6 plates. In the case of small values of feed 0.1/tooth, the standard deviation of the signal of displacements for the simulated damage of 3 plates increased by 120 %, while the peak-to-peak parameter – 120 % in comparison to the work with 6 undamaged plates. Along with the increasing feed on the tooth, those differences increased and amounted, respectively, for feed of 0.15 mm/tooth – 180 % for the standard deviation of the signal and 215 % for the peak-to-peak parameter. In the case of the highest tested value of feed on the tooth of 0.2 mm/tooth, there were lower increases than in the case of the feed of 0.15 mm/tooth since the value of the standard deviation increased by 179 % and the peak-to-peak value by 191 %.

4. Conclusions

The conducted research allowed tests concerning the impact of changes in the tooth pitch of the cutter on relative displacements in the layout tool - machined objects and allowed formulation of the following conclusions:

1. The increase of feed on the tooth, from 0.1 to 0.2 mm/cutting edge, for a tool with 6 cutting plates, results in an increased standard deviation of the signal within the range of 7.41 – 8.83 μm.
2. In the case of a tool with 3 unevenly distributed cutting plates, the increase of the feed on the cutting edge from 0.1 to 0.2 mm/cutting edge caused a change in the standard deviation within the range of 16.38 ÷ 24.72 μm.
3. In the amplitude-frequency characteristics, it is possible to distinguish characteristic components related to the process of machining and originating from the rotations: f_o – basic frequency originating from rotations (13.73 Hz), $2 \cdot f_o$ – the first harmonics (27.46 Hz), $3 \cdot f_o$ – the second harmonics (40.43 Hz), $4 \cdot f_o$ – the third harmonics (54.17 Hz), and $5 \cdot f_o$ – the fourth harmonics (67.9 Hz), $6.f_o$ – basic frequency increased by the number of cutting edges (81.63 Hz).
4. The amplitude-frequency analysis has also presented which sockets had cutting plates and which were empty. On that basis, it is also possible to monitor the wear of individual cutting plates during the machining process.

References

Adamczak, S., Zmarzły, P. and Janecki, D. (2015) Theoretical and practical investigations of v-block waviness measurement of cylindrical parts, Metrology and Measurment Systems, 22, 2, pp. 181-192.

Ambrozik, A., Ambrozik, T., Łagowski, P. and Kurczyński, D. (2014) The influence of injection advance angle on fuel spray parameters and nitrogen oxide emissions for a self-ignition engine fed with diesel oil and fame, Polish Journal of Environmental Studies, 23, pp. 1917-1923.

Bartoszuk, M, and Grzesik, W. (2011) Numerical prediction of the interface temperature using updated finite difference approach, MODELLING OF MACHINING OPERATIONS Book Series: Advanced Materials, 223, pp. 231-239.

Blasiak, S. and Zahorulko, A.V (2016) A parametric and dynamic analysis of non-contacting gas face seals with modified surfaces, Tribology International, 94, , pp. 126-137. doi:10.1016/j.triboint.2015.08.014.

Błasiak, M. (2016) Parametric analysis of piezoelectric transducer used for signal processing, in: Eng. Mech., pp. 66-69.

Mięsikowska, M. (2016) Analysis of polish vowels of tracheoesophageal speakers, Journal of Voice, 30.

Miko, E. (2005) Micro-irregularities of metal surfaces, Strojniski Vestnik-Journal of Mechanical Engineering, 51, 10, pp. 634-645.

Miko, E. and Nowakowski, Ł. (2013) A set of machine tools and laser system to measure the relative displacements (zestaw obrabiarki i systemu laserowego do pomiaru przemieszczeń względnych), PL 217 590 B1.

Nowakowski, Łukasz Mięsikowska, M. and Błasiak, M. (2016) Speech intelligibility in the position of cnc machine operator, in: Eng. Mech., pp. 422-425.

Nowakowski, L. and Wijas, M. (2016) The evaluation of the process of surface regeneration after laser cladding and face milling, in: Eng. Mech., pp. 430-433.

Pastuszko, R. (2014) Pool boiling on rectangular fins with tunnel-pore structure, in: EPJ Web Conf. Vol. 45, p. 1020.

Takosoglu, J.E. (2016) Experimental research of flow servo-valve, in: Proc. Int. Conf. Exp. Fluid Mech. 2016 (ed. Dancova, P.), Techn. Univ. Liberec, pp. 819-823.

Takosoglu, J.E., Laski, P.A., Blasiak, S., Bracha, G. and Pietrala, D. (2016) Determining the static characteristics of pneumatic muscles, Measurement and Control, 49, 2, pp. 62-71. doi:10.1177/0020294016629176.