Study Wear Tool with High-speed Milling

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Abstract. This report examined tool wear in high-speed machining of tool steel with a hardness of HRC 63. Wear monitored periodically using the device for automatic geometric correction tool (length and radius) situated in the working area of the machine. The study was conducted on milling machine RAIS M400 with CNC Heidenhain iTNC 530i.

Keywords: wear, high-speed milling, cutting tool, milling machine, CNC.

I. INTRODUCTION

Rotary dies for the production of sanitary absorbents (Figure 1) in the process of work wear [1,2], which requires their periodic sharpening i.e. reconstruction of cutting power. They are made of tool steel, where after quenching reached hardness between 60 and 63 HRC. Resharpening of these components is carried out by grinding the side surface where the process compared to the milling has a low performance [3].

Fig. 1 Rotary die for sanitary absorbents

Taking into account the stiffness of the rotary die from HRC 63 e possible to increase productivity by using high-speed milling. When sharpening the cutting edge of the rotary die due to different wear have capture greater added. This, together with the great length of the cutting edge may lead in turn to an unacceptable wear of the cutting tool and breakage. The aim of the study is to check the wear of the tool to be able to answer the question whether high-speed milling can replace grinding.

II. STUDY OF THE WEAR OF THE TOOL AT HIGH SPEED MILLING

To conduct the study used a cutting tool company SGS Series Power-Carb with AlTiN coating. This series is recommended for machining of molds for injection molding of forms for casting and the production of dies [4, 5]. Tools of this series are characterized by high quality of the machined surface of hardened steel with a hardness of 65 HRC. The study is done on milling machine RAIS M400 with CNC Heidenhain iTNC 530i [6]. Fig. 2 shows the establishment of a workpiece, which is essentially a rotary die obsolete.

Fig. 2 Establish a workpiece

Wear on the tool radius is controlled using the findings in the working area of the machine device for automatically determining the length and tool radius (Tool Touch Probe TT140). This is a built-in CNC cycles. The measurement of the tool radius is performed with cycle 482 (Fig.3), wherein the measurement is possible to carry out in two ways - with continuous rotation of the instrument and measurement of each tooth separately, in which case it must first be set to the number of the teeth of the tool. In this way, the system automatically determines the highest tooth and it introduces a correction. After measurement, the values recorded in the sub-instruments.

Study of measurement accuracy Tool Touch Probe TT140

The study of the accuracy of the TT 140 is necessary to examine to what extent will be reliable survey data. It will be held by being made 20 measurements for each of the aforementioned methods.
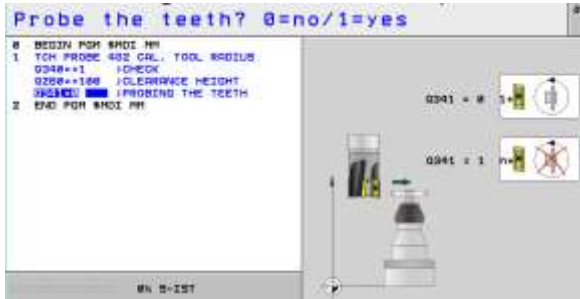
Fig. 3 Measuring cycle 482

Accuracy in the rotating tool

Used measurement cycle 482 (fig. 3). This cycle is only measured tool radius. Depending on what is set in parameter 341 (fig. 3) measured on the rotating tool (parameter 341 = 0) or measured each tooth individually (parameter 341 = 1). In Table 1 shows the measurement results.

Table 1
Results of measurement in rotating tool

№	Tool radius [mm]	Deviations DR [mm]	№	Tool radius [mm]	Deviations DR [mm]
1	4	-0,0155	11	4	-0,0176
2	4	-0,0156	12	4	-0,0217
3	4	-0,0219	13	4	-0,0157
4	4	-0,0181	14	4	-0,0210
5	4	-0,0104	15	4	-0,0218
6	4	-0,0227	16	4	-0,0165
7	4	-0,0247	17	4	-0,0161
8	4	-0,0262	18	4	-0,0108
9	4	-0,0225	19	4	-0,0212
10	4	-0,0108	20	4	-0,0134

Results are processed statistically to determine what is the accuracy of the measurement. Arithmetical mean value $\bar{\Delta}$ is defined by equation (1) and residual errors in equation (2).

$$\bar{\Delta} = \frac{1}{n}\sum_{i=1}^{n}\Delta_i \tag{1}$$

$$\delta_i = \Delta_i - \bar{\Delta} \tag{2}$$

With the obtained values are determined standard deviation equation (3) and mean square deviation S_X in equation (4).

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\delta_i^2} \tag{3}$$, at n<30

$$s_{\bar{x}} = \frac{s}{\sqrt{n}} \tag{4}$$

Confidence limits ± ε is defined in equation (5) at the confidence level γ = 0,99, then determine confidence limits in equation (6).

$$\varepsilon = t_\gamma . s_x \tag{5}$$

$$(\bar{X} - t_\gamma . s_{\bar{X}}) < E < (\bar{X} + t_\gamma . s_{\bar{X}}) \tag{6}$$
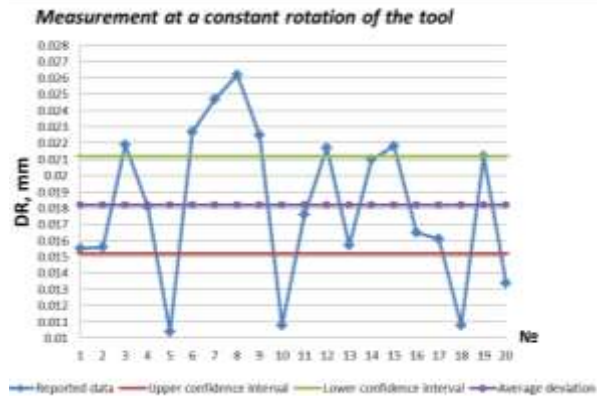
The results are presented graphically in fig. 4.

Fig. 4 Graphical representation of the accuracy of the rotating tool

Accuracy of each tooth individually

Again using the measuring cycle 482 as a parameter 341 is set to 1. In the table parameters of the tool set number of teeth.

Table 2
Measurement results for each tooth individually

№	Tool radius [mm]	Deviations DR [mm]	№	Tool radius [mm]	Deviations DR [mm]
1	4	-0,0166	11	4	-0,0172
2	4	-0,0132	12	4	-0,0160
3	4	-0,0134	13	4	-0,0170
4	4	-0,0128	14	4	-0,0149
5	4	-0,0141	15	4	-0,0133
6	4	-0,0176	16	4	-0,0166
7	4	-0,0168	17	4	-0,0168
8	4	-0,0165	18	4	-0,0179
9	4	-0,0160	19	4	-0,0174
10	4	-0,0158	20	4	-0,0173

The measurement results are presented in Table. 2. In Fig. 5 presents graphically the data processed statistically by the equations (1) to (6).

The standard deviation of the first case (a rotating tool) is S = 0.0047, and in the second case, S = 0.0016. Mean square error in the measurement of rotation of the tool is SX = 0.0011, while the second case when measured each tooth individually, the mean square error is SX = 0.0004.
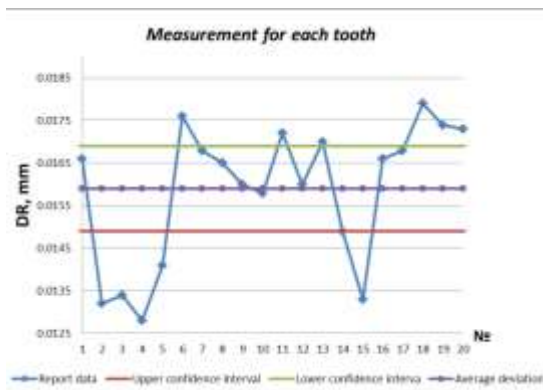
Fig. 5 Graphical representation of accuracy in measuring each tooth individually

From these results, it is found that the method which measures each cutting tooth individually is more accurate and will be used in the experiment to check the wear of the cutting tool at high-speed cutting of steel with a hardness of 63 HRC.

Study of wear on the cutting tool at high speed milling

SGS is used tool Series Power-Carb coated with AlTiN and tooth 6, wherein the treatment is performed with circular interpolation. Control program is implemented with the help of parameters and cycles meeting certain logical conditions. At the beginning of the control program introduces parameters such as diameter and height of the workpiece feeding speeds jutting out into the addition and routing, cross-filing and more. After each pass of 5 instrument is measuring its radius. Fig. 6 shows the control program.

```
 0  BEGIN PGM M400 MM
 1  FN 0: Q1 =+156
 2  FN 0: Q2 =+300
 3  FN 0: Q3 =+152
 4  FN 0: Q4 =+0.25
 5  FN 0: Q5 =+0
 6  FN 0: Q6 =+0
 7  FN 0: Q7 =+0
 8  FN 0: Q8 =+5
 9  FN 0: Q9 =+4
10 FN 0: Q10 =+3000
11 FN 0: Q11 =+3000
12 FN 0: Q12 =+6000
13 FN 0: Q13 =+0
14 FN 4: Q14 =+Q1 DIV +2
15 BLK FORM 0.1 Z  X-Q14  Y-Q14  Z-Q2
16 BLK FORM 0.2  X+Q14  Y+Q14  Z+0
17 TOOL CALL 2 Z SQ12
18 LBL "IZMERVANE"
19 TCH PROBE 482 CAL. TOOL RADIUS ~
   Q340=+1    ;CHECK ~
   Q260=+100  ;CLEARANCE HEIGHT ~
   Q341=+1    ;PROBING THE TEETH
20 L  X+0  Y+0  Z+80 R0 FMAX
```

```
21 FN 0: Q13 =+0
22 LBL 0
23 LBL "FREZOVANE"
24 FN 1: Q5 =+Q5 + +Q4
25 FN 2: Q6 =+Q1 - +Q5
26 FN 1: Q7 =+Q6 + +Q4
27 FN 1: Q13 =+Q13 + +1
28 CYCL DEF 257 CIRCULAR STUD ~
   Q223=+Q6  ;FINISHED PART DIA. ~
   Q222=+Q7  ;WORKPIECE BLANK DIA. ~
   Q368=+0   ;ALLOWANCE FOR SIDE ~
   Q207=+Q10 ;FEED RATE FOR MILLNG ~
   Q351=+1   ;CLIMB OR UP-CUT ~
   Q201=-Q9  ;DEPTH ~
   Q202=+Q9  ;PLUNGING DEPTH ~
   Q206=+Q11 ;FEED RATE FOR PLNGNG ~
   Q200=+2   ;SET-UP CLEARANCE ~
   Q203=+0   ;SURFACE COORDINATE ~
   Q204=+50  ;2ND SET-UP CLEARANCE ~
   Q370=+1   ;TOOL PATH OVERLAP
29 CYCL CALL POS  X+0  Y+0  Z+0 FMAX
M3
30 LBL 0
31 FN 15: PRINT Q108 /Q7 /Q5 /Q6 /Q13
32 FN 9: IF +Q13 EQU +Q8 GOTO LBL
"IZMERVANE"
33 FN 11: IF +Q6 GT +Q3 GOTO LBL
"FREZOVANE"
34 END PGM M400 MM
```

Fig. 6 Control program

The study was realized, it was made five attempts to change the regime of cutting. In Table. 3 shows the results of well skilled in mode 1 cutting: cut feed 3000 mm / min (feed per tooth 0.083 mm), spindle speed 6000 min-1, step over 0.25 mm, diameter of the workpiece Dw = 158.85 mm.

Table 3
Result of Experiment 1

Experiment 1			
Tool radius, [mm]	DR, [mm]	Dw, [mm]	Distance L, [mm]
4		158.6	498.2566
		158.35	497.4712
		158.1	496.6858
		157.85	495.9004
	0.0147	157.6	495.1150
$\sum L$, [mm]			2483.4290
Wear, [mm]			-0.0026

A negative sign is accidentally received and due to the dissipation of the measurement results with Tool Setter TT140.

Experiment 2 was conducted in the following mode: cut feed 2000 mm / min (feed per tooth 0.055), spindle speed 6000 min-1, step over 0.32 mm, diameter of the workpiece Dw = 157,6 mm (Table. 4)

Table 4
Result of Experiment 2

Experiment 2			
Tool radius, [mm]	DR, [mm]	Dw, [mm]	Distance L, [mm]
4		157.28	494.1097
		156.96	493.1044
		156.64	492.0991
		156.32	491.0938
	0.0147	156.00	490.0884
	$\sum L$, [mm]		2460.4954
	Wear, [mm]		0.0059

Experiment 3 was conducted in the following mode: cut feed 3000 mm / min (feed per tooth 0.083), spindle speed 6000 min-1, step over 0.25 mm, diameter of the workpiece Dw = 156 mm (Table. 5)

Table 5
Result of Experiment 3

Experiment 3				
Tool radius, [mm]	DR, [mm]	Dw, [mm]	Distance L, [mm]	Wear [mm]
4	0.0201	157.28	2434.73	-0.0005
	0.0231	156.96	2419.03	0.003
	$\sum L$, [mm]		4853.76	
	Wear, [mm]			0.0025

Experiment 4 - mode: cut feed 3000 mm / min (feed per tooth 0.071), spindle speed 7000 min-1, step over 0.25 mm, feed per tooth 0.055, diameter of the workpiece Dw = 153.25 mm (Table. 6)

Table 6
Result of Experiment 4

Experiment 4			
Tool radius, [mm]	DR, [mm]	Distance L, [mm]	Wear [mm]
4	0.0268	4684.9	0.0043
	0.0273	3691.37	0.0005
	0.0282	5061.89	0.0009
	0.0299	4983.35	0.0017
	0.0305	4904.81	0.0006
	0.0318	4826.27	0.0016
	0.0363	8347.99	0.0013
	0.0394	8093.52	0.0048
	$\sum L$, [mm]	51733.36	
	Wear, [mm]		0.0163

In the last 5 Experiment was changed only step over = 0.15 mm. The results are shown in Table. 7

Table 7
Result of Experiment 5

Experiment 5			
Tool radius, [mm]	DR, [mm]	Distance L, [mm]	Wear [mm]
4	0.0407	4384.87	0.0013
	$\sum L$, [mm]	4384.87	
	Wear, [mm]		0.0013

When the last attempt tool was completely worn out. In the treated surface was obtained yellowish-brown mark (fig. 7), from which it is clear that the tool is worn. This path is obtained by burning the material in the cutting zone. Fig. 8 is visible wear of the tool.

Fig. 7 Marks on the treated surface related to tool wear

Fig. 8 Wear the instrument after completion of the study

The results of the experiment are summarized in Table. 8. From these data it is clear that the parameters used tool travels nearly 66 meters before being completely worn out.

Table 8
Summarized Results of the Study

Total distance, [mm]	66 000
Total wear, [mm]	0.0234

Fig. 9 is a graph of tool wear compared traveled road. The amount of volume of the milled material is 45 492 mm^3.
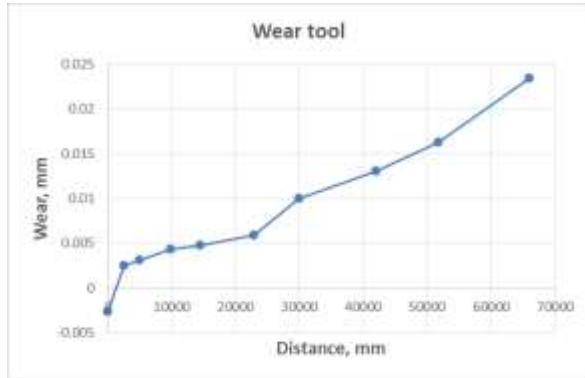
Fig. 9 Wear the instrument to the covered distance

III. CONCLUSION

From the results can be drawn the following conclusions:

1. In high-speed milling filled with these modes, tool wear is minimal compared to the distance covered;

2. From Fig. 9 it can be seen that with some initial wear, there is a slow minimum wear increase as compared to the way traveled. It is explained by the fact that in the initial stage of operation the wear of the tool is more intense and it is not in line with the way traveled;

3. Wear compared to the distance covered is negligible, and the life of the tool is much longer than prescribed by the manufacturer;

4. High-speed milling can replace the grinding operation at sharpening the cutting edge of the rotary die;

5. With high-speed milling, productivity increases about 2-3 times compared to grinding.

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