INFLUENCE OF TOOL CLAMPING ON TOOL WEAR

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Abstract

The paper deals with the problem of clamping shank tools in conventional milling operations and how it influences tool wear and tool life. In the experiment, four different types of clamps were used - spring collet, shrink fit tool holder and two hydraulic chucks. Tools used for the experiment were uncoated monolithic solid carbide end mills. For every clamping setup, tool wear tests were carried out, and times it took to reach set value of wear were measured. Time values were compared to determine how the clamping mechanism can influence tool wear, as well as what clamping method produced the best results. Aim of the research was to measure the influence of tool clamping on tool wear. It was discovered that the best tool life was achieved with the spring collet, and worst with hydraulic chuck.

Keywords: milling; tool clamping; solid carbide mills; tool life; tool wear

1. Introduction

Choice of tool clamping solution is one of the links in the machine tool – workpiece interaction that can get easily overlooked, especially when dealing with conventional machining [1]. Clamping system should be sufficiently rigid, while efficiently transferring the torque from the spindle to the tool [2]. Vibrations of the tool during the milling process are common cause of increased tool wear, therefore clamping system should work to damp the vibrations [3, 4]. Another aspect to consider might be safety or ergonomics of the tool clamps, because it's one of the parts of the machine tool that the workers often handle manually [5]. There is variety of different tool clamping systems made by various manufacturers, for universal applications, as well as specialized ones [6], meanwhile, new clamping solutions are being actively developed as well [7]. Every clamping system has a set of parameters that should determine its use for a specific application, however, the effect of the tool clamping on the tool wear has not been given due consideration, in contrast with the workpiece clamping solutions [8, 9, 10]. One of the main areas where tool clamping is especially important is when machining with tools with long overhang [11]. Since tool clamping can affect the productivity and economy of the manufacturing process, highlighting its importance in relation to the technology of milling should be in order [12]. In the experiment described in the article, four different types of tool clamping solutions were used and tool wear was measured during the machining process. Measured factor of wear was average flank wear width (VB), with the $VB_{\max}$ value set to 0,3mm.

2. Materials and methods

Materials, equipment and machinery used for the experiment are described in this section.

Tools used for the experiment were monolithic solid carbide mills that were manufactured from solid carbide rods on the Reinecker WZS60 tool grinding machine in the Centre of Excellence of 5-axis Machining at the Faculty of Materials Science and Technology of Slovak Technical University. Specific grade of the cemented carbide was PCG F10 that is equivalent to K20-K30 by ISO. Detailed material specifications can be found in Table 1 [13].

PCG Grade	ISO group	Co volume	Hardness HV30	Hardness HRA	Density
F10	K20-K30	10%	1580	92,0	14,35 kg.m ⁻³

Table 1. Tool material specifications [13]

Tool parameter	Value
Cutting diameter	9,9 mm
Maximum depth of cut	20 mm
Tool length	85 mm
Shank diameter	10 mm
Center diameter	5 mm
Cutting edge count	3
Flute helix angle	45°
Rake angle γ	10°
Flank angle α_l	12°

Table 2. Tool parameters

Material of the machined workpiece used for the tool wear test was medium carbon steel grade C45 ISO 683-1:2018, with dimensions of 140x140x100 mm.

Chemical composition (%)							
C	Mn _{max}	Si _{max}	P _{max}	S _{max}	Cr _{max}	Ni _{max}	Mo _{max}
0,42-0,50	0,50-0,80	0,40	0,045	0,045	0,40	0,40	0,10

Table 3. Workpiece material chemical composition

Four different clamping systems were used in order to compare their influence on the machining process and resulting tool wear.

Clamp type	Manufacturer	Runout [mm]	Length [mm]
Spring collet TYP 5675	SECO	max 0.01	100
Shrink fit tool holder SFD 10x120	SECO	max 0.003	120
Hydraulic chuck CoroChuck 930	Sandvik Coromant	max 0.003	100
Hydraulic chuck TENDO E Compact 206406	Schunk	max 0.003	80

Table 4. Basic parameters of clamps used for the experiment

Digital optical microscope Dino-lite was used to observe and measure the tool wear. For every clamping system, tool wear tests with identical constant cutting parameters were carried out.

Parameter	Value
Cutting speed	100 m.min ⁻¹
Feed per tooth	0.03 mm
Feed rate	280 m.min ⁻¹
Axial depth of cut	0.5 mm
Radial depth of cut	5 mm
Tool overhang	38 mm

Table 5. Cutting parameters of the tool wear tests

Cutting fluid was not used in the tests, tools were air cooled only. Linear NC paths were generated in the CAM software Autodesk Powermill. Tools were measured after one minute of milling, subsequently tools were measured in five minute intervals during milling. Tool wear criterion VB_{max} was set for 0.3 mm, this value was reached after 41 minutes of machining.

3. Results and discussion

In the graph on Figure 1, we can see the comparison of the development of values of VB in time. Tool clamped in hydraulic chuck Tendo E Compact was found out to last the least amount of machining time, as the set criterion of wear was reached most quickly. This result was used as a baseline for the other clamping types. Hydraulic chuck CoroChuck 930 has contributed to a minor improvement of the tool life, as the tool in this holder lasted 18 seconds more than with the aforementioned chuck. Tool in the shrink fit holder registered more substantial increase in the tool life, lasting 54 seconds more. Best result was achieved while using the spring collet, tool in this clamping system lasted 4 minutes 57 seconds longer. These time values are illustrated in the figure 2.

Fig. 1. Comparison of clamping systems in relation to the value of VB

Fig. 2. Comparison of clamping systems in relation to the time

Table 6 contains differences in time in seconds it took for the tool in the specified holder to reach set criterion of VB critical. It can be noted that for a single tool life time, values nearing 5 minutes are significant from the standpoint of

productivity in machining, since, extrapolating this time reduction in mass production can provide substantial manufacturing cost reduction.

Clamp type	Spring collet TYP 5675	Shrink Fit SFD	CoroChuck 930	Tendo E Compact
Spring collet TYP 5675	0	165	279	297
Shrink Fit SFD	-165	0	54	72
CoroChuck 930	-279	-54	0	18
Tendo E Compact	-297	-72	-18	0

Table 6. Tool life differences comparison in seconds

4. Conclusion

Purpose of the experiment that was carried out was to investigate the influence of tool clamping on tool wear. Based on the lower clamping force and higher runout for the spring collet, it could be assumed that the tool would wear out faster when clamped in this type of holder. Hydraulic chucks are generally considered to be the best option when it comes to tool holders, because of the higher clamping force, better vibration damping capabilities, as well as lower runout compared to other types of clamping solutions. However, based on the experiment results, these assumptions were not verified. According to the measured results, highest tool life was observed for the spring collet, slightly worse results were achieved for the shrink fit holder, where the tool lasted 3 minutes 45 seconds less than in the spring collet. Hydraulic chucks did not prove to have significantly positive influence on the tool wear, tool used with CoroChuck hydraulic chuck took 54 seconds less to reach the set tool wear criterion than the tool used with the shrink fit holder. Tool clamped in hydraulic chuck Tendo E compact lasted 18 seconds less than the aforementioned hydraulic chuck from different manufacturer. These values obtained from the experiment indicate, that the claims of tool holder manufacturers about the positive influence of their clamping solution on the tool life might not always be true. It should be noted that these results were only achieved for specific cutting tools and cutting parameters, it is entirely possible that different conclusion could be reached if the variables of the experiment were modified. Although tool wear is definitely an issue to consider when choosing the proper tool clamping system, there are other aspects to take into account. Each clamping system has its advantages and disadvantages that can influence the productivity of the manufacturing process, so depending on the intended use, every type of clamping solution should be given due consideration in relation to the final desired outcome.

By conducting the experiment, we have determined the best available clamping system so that we can minimize the influence of clamping system on the machining process in the future experiments focused on the wear behavior of the solid carbide mills with prepared edges.

5. Acknowledgments

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