SURFACE ROUGHNESS OF PARTS MADE TITANIUM ALLOYS MACHINED WITH FACE MILL OF ORIGINAL CONSTRUCTION

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Abstract: Importance of the use of titanic alloys is shown in many industries of engineer. Problems which arise at their processing are described that negatively affect process productivity and indicators of surface quality and etc. This is especially important when machining plane surfaces of parts by face milling. The surface roughness depends first of all on geometrical parameters and the shape of the cutting edge of the tool insert that contacts the processed surface. Therefore it was developed an original design of face mill with a stepped insert arrangement with a cylindrical front surface, and at the same time process productivity was improved.

Expediency of use of the proposed design of a face mill it is proved by comparative experimental studies of influence of a form of a front surface of round inserts on roughness of the machined surface of parts from titanium alloy VT1-0. The comparison was made between the machining of the face mill with a cylindrical front insert surface and a standard face mill with round inserts (ISO 6462:2011). A non-composite second-order plan was received results of the study were obtained for the conditions of machining titanium alloy.

The profile of the machined surface was investigated to evaluate the roughness Ra and it was determined that, with the maximum cutting modes, the face mill of the original design provided a lower roughness of the machined surface than a standard mill. The optimum cutting modes are determined by the criterion of the roughness of the machined surface of parts made of titanium alloy VT1-0 and the process productivity of face milling. The proposed face mill provides a 1.26 time increase in productivity compared to machining a standard face mill while obtaining minimal roughness.

Keywords: process productivity, face mill, titanium alloys, cylindrical front surface.

1. Introduction

Many industries are increasingly using difficult-to-cut materials, including titanium alloys, which have special physical and mechanical properties and are characterized by low machinability. The particular interest is the machinability of titanium alloys having a high melting point (1670 °C), specific gravity (4.5 g/cm^3), high strength and corrosion resistance [1]. Titanium alloys are used for the most responsible parts due to their high cost and complexity [2].

Most of the operational properties of parts are determined by the contact interaction, which is characterized by various parameters, including roughness and deviations from the geometric form of the interfaced surfaces [3, 4]. First of all, the surface roughness depends on the geometrical parameters and the shape of the insert cutting edge [5, 6]. The cutting of titanium alloys is accompanied by temperature increase in the cutting zone, adhesion, welding and sticking of the chips to the insert, increased tool wear, which negatively affects the process productivity, the quality machined surface, etc. [2, 7]. This is especially important when processing extended precision plane surfaces can be conjugated, and which are often machined by a face milling.

Some studies have confirmed the possibility of improved productivity in the introduction of tools with a cylindrical front surface of the cutting elements [2, 5, 8, 9]. The analysis of existing designs of face mills showed the need to develop a new tool with stepped cutting schemes, an identical departure of inserts, more uniform load distribution on each insert and round insert shape [8–10].

Relevant scientific and technical task is increase in process productivity of parts from titanium alloys due to development of new designs of face mills which at the same time provide the best surface quality of the cut in comparison with standard face mills.

The purpose of the study is increase in process productivity while ensuring the required quality of the machined surface of parts made of titanium alloys by developing new designs of face mills with a cylindrical front surface of inserts.

For achievement of the goal the following tasks were set:

1) to execute experimental studies of processing of plane surfaces of parts from titanium alloys the developed and standard mills;

2) to compare the received results and to define the optimum modes of exploitation of the selected of face mills.

2. Methods

Experimental studies of the plane surface machined were performed on a vertically milling machine model 6P12. Workpieces made of titanium alloy VT1-0 (dimensions: 80×250×80 mm). Tool material – VK-8 hard alloy. The diameter of the face mills – D=200 mm, the number of inserts – z=12. The processing was carried out by a developed stepped face mill with a cylindrical front inserts surface [10] and a standard face mill with round inserts [11] in accordance with the plan (Table 1). The preliminary researches made it possible to suggest rational values of the basic design parameters of the developed mill, depending on the required cutting depth [9]. Thus, for a cutting depth of 3 mm, it is advisable to choose a insert radius of 5,4 mm, the angle of inclination of the cutting units is 6°, and the front angle is –16°.

To evaluate the effect of the form of the front surface of the face mill inserts on the roughness of the machined surface by variables, the following factors were adopted: cutting speed and feed.

Based on experimental studies [8, 9, 12], levels and intervals of factor variation were selected (**Table 1**).

To evaluate the surface roughness Ra, a surface profile study was performed in accordance with ISO 4287-2012 on the mode profilometer Caliber 170311, equipped with a computer measuring system.

Table 1
Levels and intervals of factor variation

Factors	Levels of factors		
	top (+1)	**basic (0)**	**lower (–1)**
V – cutting speed, m/min	100.5	78.5	62.8
S – feed, mm/min	80	63	50

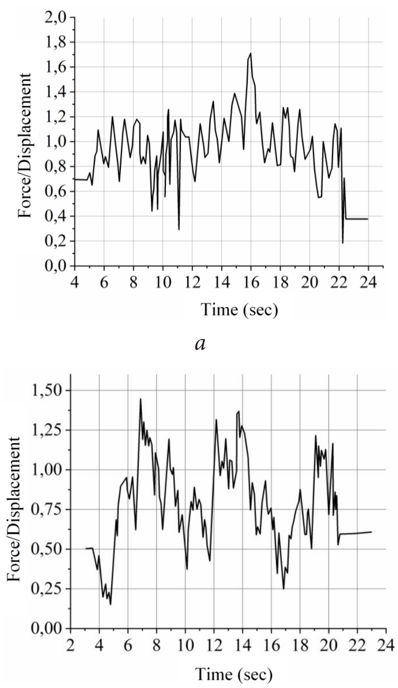
3. Results

For the conditions of machined of the titanium alloy VT1-0, a non-composite second-order plan was implemented, the matrix and the results of the study are presented in **Table 2**.

The cutter provides a less surface roughness than the standard one (Ra 0.72 and Ra 0.84 µm, respectively) at maximum cutting modes (**Fig. 1**).

Table 2
Results of the surface roughness study

No.	x_0	x_1	x_2	*V*, m/min	*S*, mm/min	Surface roughness Ra, μm	
						Standard mill	Developed mill
1	+	+	+	100.5	80	0.84	0.72
2	+	+	–	100.5	50	0.65	0.63
3	+	–	+	62.8	80	0.76	0.65
4	+	–	–	62.8	50	0.72	0.71
5	+	0	0	78.5	63	0.69	0.66
6	+	0	+	78.5	80	0.82	0.67
7	+	+	0	100.5	63	0.68	0.62
8	+	–	0	62.8	63	0.71	0.64
9	+	0	–	78.5	50	0.71	0.68



a

b

Fig. 1. The profile of the machined surface
(*n*=160 rpm, *s*=80 mm/min, *t*=3 mm):
a – standard mill (*Ra* 0,84 μm); *b* – developed mill (*Ra* 0,72 μm)

The influence of cutting modes on the surface roughness of parts made of titanium alloy VT1-0 (**Fig. 2**).

When machining with a standard face mill, a minimum value of the surface roughness *Ra* of 0.65 μm (*s*=50 mm/min, *v*=100.5 m/min) was obtained, and the processing developed with *Ra* 0,62 μm (*s*=63 mm/min , *v*=100.5 m/min).

For the whole range of cutting modes used during the experiment, the process productivity of the face milling was determined. The results obtained are shown in **Fig. 3**.

The process productivity of the developed mill is 1,26 times higher than that of the standard mill.

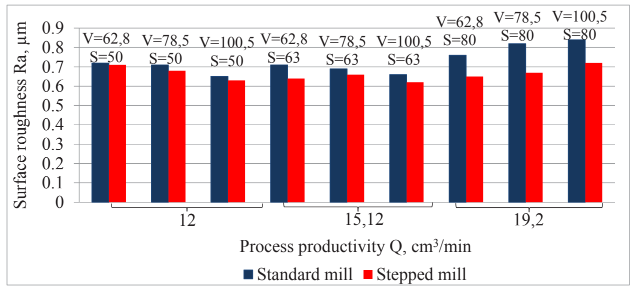


Fig. 3. Influence of cutting modes on surface roughness and process productivity (V – m/min, S – mm/min)

Based on the results of the experiment, the optimal cutting modes were determined according to the criterion of surface roughness (*Ra* 0,62 μm) – *s*=63 mm/min, *v*=100,5 m/min.

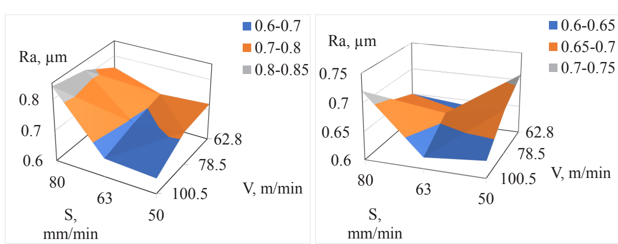
Therefore, the hypothesis of the use of face mills with a cylindrical front surface to improve the process productivity of titanium alloys while obtaining a quality machined surface can be considered to be confirmed.

4. Discussion and conclusions

When using the developed face mill with a cylindrical front inserts surface, the process productivity of plane surfaces made of titanium alloy VT1-0 in 1,26 times is achieved by increasing the feed (from 50 mm/min to 63 mm/min) compared to using a standard face mill. At maximum cutting modes, the developed mill provides less surface roughness than the standard mill – *Ra* 0,72 and *Ra* 0,84 μm, respectively.

The previous works of the authors also found that the processing of the developed face mill reduces the impact load during the cutting of the insert, the tangential component of the cutting force, the vibration level, compared with the processing of the standard face mill. All this is explained by the design features of the cutter. The use of inserts with a cylindrical front surface is characterized by a change in the angles of inclination and angles in the plan along the cutting edge. This causes a non-uniform plastic deformation of the cut layer along the cutting edge and affects the quality of the surface.

Thus, the use of face mills with a cylindrical front surface of the inserts is promising to obtain parts with high performance. The developed scientific approach can be used to increase the process productivity of face milling of difficult-to-cut materials of other brands with the use of other tool materials.



a *b*

Fig. 2. The influence of cutting modes on the surface roughness: *a* – standard mill, *b* – developed mill

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Received date 27.09.2019
Accepted date 29.10.2019
Published date 23.11.2019