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Optimization of Micro-Textured Tools Geometric Parameters in Turning of 17-4PH Stainless Steel

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ABSTRACT: In this study, the effect of microtextures parallel to the cutting edge on the rake face of cutting tools during the turning process of 17-4PH steel was investigated. The depth, width, and distance of micro-textures were studied. Turning tests were performed with the created tools and the cutting force was measured by a dynamometer. The results showed that by increasing the width of microgrooves, the cutting force first decreases and then increases. This trend shows that the width of the microgrooves has an optimal value in which the cutting force during the turning process is minimal. Also, the cutting force is reduced by increasing the depth of microgrooves. By increasing the distance of microgrooves, it was found that the cutting force has increased. Based on the optimization results, the optimal values of the parameters of width, depth, and distance of the microgrooves are 126 µm, 15 µm, and 200 µm, respectively. The calculated error percentage for optimization validation was 5.81%, which indicates the high accuracy of the optimization process in the Design-Expert software. The deflection of the workpiece was achieved with a tool with an optimal microgroove of 30 µm and with a plane tool equal to 62 µm, which shows a 51.6% reduction with a textured tool. In fact, the accuracy of the machined part was improved with microtextured tools.

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1- Introduction

Today, in the industry, the need to increase the life of mechanical parts by controlling friction and wear has increased. In the last decade, the functional conditions of the mechanical parts in contact with each other have become more severe, as a result, the maximum thickness of the lubricant between the involved parts has reached the level of their surface roughness [1]. Therefore, researchers are interested in improving their functional conditions by changing the microtopography of surfaces. Surface texturing is one of the possible solutions to improve the tribological characteristics of mechanical parts. The texture of the surfaces acts as lubricants accumulation zones and improves the tribological properties of the surfaces [2, 3].

The wear performance of tungsten carbide tools on which parallel, circular and hybrid microtextures were created was investigated by Sahu et al [4]. The results showed that the wear of the tool with parallel texture is reduced by 32% compared to plain tools.

Machining of Inconel 718 with the textured tool by Gupta et al showed reduced tool wear, improved workpiece surface finish, and reduced cutting temperature compared to the untextured tool. The results showed that the textured tool can be used in the industry as an optimal tool [5].

The review of previous research shows that in most of them, the performance of the different texture shapes has been compared with each other and with the plain tool. Very few works have optimized the dimensions of the microtexture parameters, therefore, in this article, the optimal dimensions of the linear microtexture were obtained to lead to the minimum cutting force and increase the machining accuracy.

2- Methodology

The turning tests were performed on a stainless steel 17-4PH round bar. When turning this alloy, it is necessary to reduce the cutting forces in order to reduce the elastic deformation and, as a result, to increase the accuracy of machining. The experimental investigation was carried out on a TB50NR Lathe. Cemented tungsten carbide inserts were used in experiments. In addition, cutting forces were measured using Kistler 9121 dynamometer. The microgrooves were made using a fiber laser at the rake face of the tools. The wavelength, repetition rate, and scanning speed were 1064 nm, 600 kHz, and 100 mm/s, respectively.

Machining parameters including cutting speed, feed rate, and depth of cut are considered constant in this study and are selected from the catalog of the tool manufacturer. The cutting depth was 1 mm, the feed rate was 0.2 mm/rev, and the cutting speed was 145 m/min. The texture parameters of

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Table 1. Experimental tests parameters and their levels

parameter	levels		
	1	2	3
Microgroove width w (μm)	100	150	200
Microgroove depth d (μm)	5	10	15
Microgroove pitch p (μm)	200	250	300

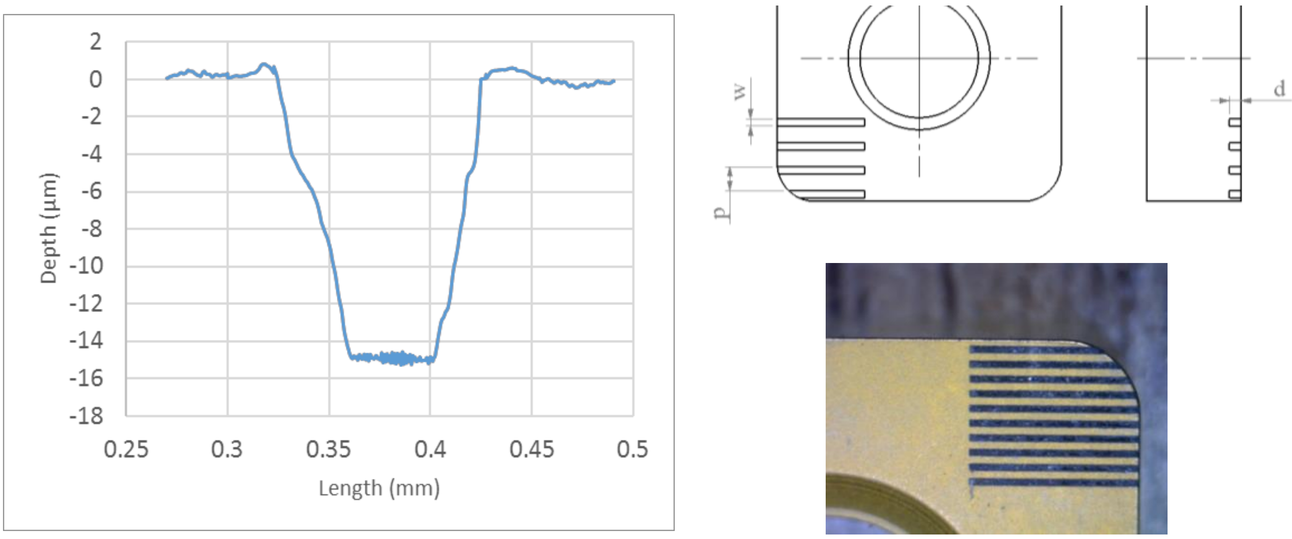

Fig. 1. Optical image of the developed textured tool and cross-section of microtexture

the cutting tool include width w, pitch p, and depth d. Table 1 shows the parameters of the experimental tests and their levels.

The images of the rake face and the cross-sectional profile of the textured tools are presented in Fig. 1. In this figure, p, w, and d indicate the pitch, width, and depth of the microgrooves, respectively.

3- Results and Discussion

The effect of the pitch of the microgrooves on the cutting force for different depths and widths of the microgrooves is shown in Fig. 2. According to these graphs, it is clear that the cutting force decreases with the decrease in the pitch of the microgrooves. The reduction of cutting force is attributed to the reduction of the effective tool and chip contact length.

The effect of the width of the microgrooves on the cutting force for different depths and pitches of the microgroove is shown in Fig. 3. According to this chart, it is clear that by increasing the width of the microgrooves, the cutting force first decreases and then increases. This can be explained by the way that the length of contact between the tool and the chip decreases by increasing the width of the microgrooves, which leads to a decrease in the cutting force. Contrary to this, when the width of the microgrooves is very large, the chip bends towards the inside of the microgroove, which finally leads to an increase in the contact length; Therefore, the cutting force increases. As a result, the width of the microgrooves has an optimal value in which the minimum cutting force is produced.

The effect of the depth of the microgrooves on the cutting force is presented in Fig. 4. From this graph, it is clear that the cutting force decreases with the increase in the depth of microgrooves. The debris is trapped inside the microgrooves, and in this way texturing the surface can prevent adhesive wear. The ability to trap particles resulting from abrasion increases with increasing the depth of microgrooves. In fact, when the chip passes through the rake face, shallow grooves are quickly filled with debris and lose their effectiveness in reducing force.

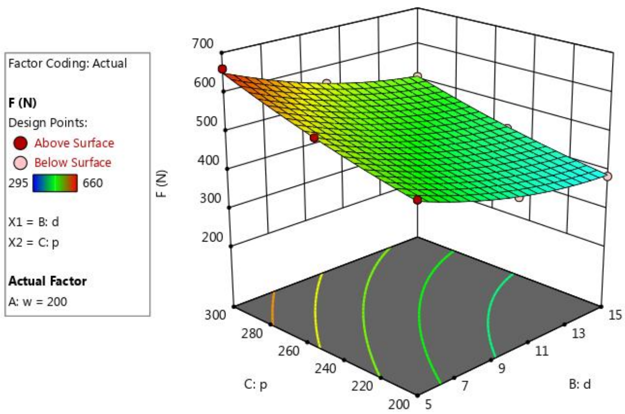

Fig. 2. Cutting force vs depth and pitch of the micro-texture, the width of the microtexture w = 200 µm

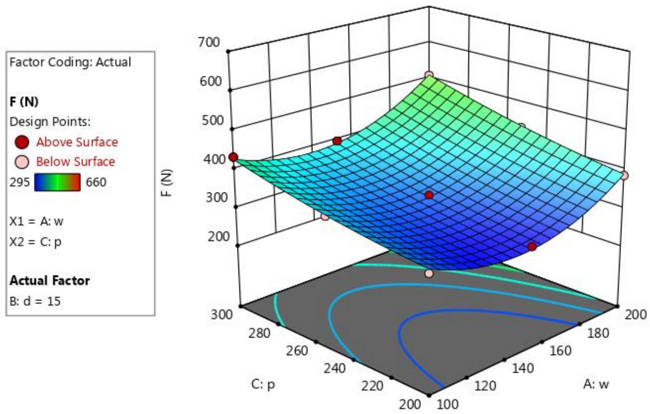

Fig. 3. Cutting force vs width and pitch of the micro-texture, the depth of the microtexture d = 15 µm

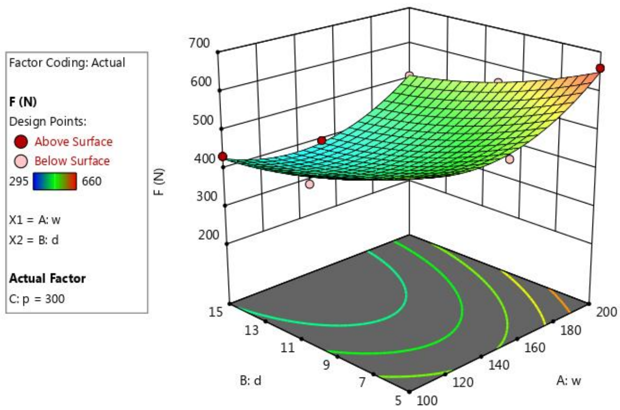

Fig. 4. Cutting force vs width and depth of the micro-texture, the pitch of the microtexture p = 300 µm

4- Conclusion

In this study, the effect of microtextures parallel to the cutting edge on the rake face of cutting tools during the turning process of 17-4PH steel was investigated. The results of the research are summarized as follows:

By reducing the pitch of the microgrooves, the cutting force decreases. The reduction of cutting force is attributed to the reduction of the effective tool and chip contact length. The width of the microgrooves has an optimal value in which the cutting force of the turning process is minimal. Finally, by increasing the depth of the microgrooves, the cutting force of the turning process decreases.

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