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THE INFLUENCE OF DRAG FINISHING ON CARBIDE END MILLS MANUFACTURED IN DIFFERENT DIAMETERS

Ridvan Tenk & Anil Akdoğan

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Abstract

The purpose of this paper is to find out how different diameter milling tools are affected by drag finishing. In order to produce a high performance tool, it is not enough to determine the rake angle, clearance angle and other important geometries alone. In addition to these, carbide tools must be finished to improve the surfaces and cutting edges produced by grinding method. The most important benefit of additional finishing on cutting tools is the rounding of sharp corners and the smoothing of surfaces. In this study, experimental investigations are presented to analyse the effects of drag finishing operation on solid carbide milling cutter production. Solid carbide milling cutters with diameters of 6, 8, 10, 12 mm were machined by drag finishing and the cutting edge geometry and surface roughness were analysed by means of 3D optical measurement. The results of the finishing rate on the cutting tool due to the contact density between the workpiece and the abrasive medium are explained.

Keywords: Carbide end mill manufacturing; Drag finishing; Cutting edge preparation; Roughness; 3D optical measurement

1. Introduction

Solid carbide milling cutters have complex geometries that are difficult to produce, and it is important to finish the surfaces formed during grinding. Therefore, cutting edge preparation is an essential production process in tool manufacturing. Today, the machining industry needs high productivity and consistent quality of the tools used. These needs can be met by edge preparation applied to cutting tools [1]. Cutting edge preparation, in addition to increasing the mechanical strength, provides better wear resistance of the tool by reducing chipping and crack formation along the cutting edge. Besides, the adhesion ability of the coating to be applied to the cutting tools is increased by cutting edge preparation and the coating process can be facilitated [2], [3], [4]. The most important effect of finishing on cutting tools is the rounding of sharp corners and smoothing of surfaces. Cutting edge rounding is the process of blunting the cutting edges after grinding the tool. Cutting edge shape and cutting edge condition are very important for machining operations. Also, the quality of the workpiece surface is affected by the shape of the cutting edge [5]. As a result of rounding the cutting edges, the problem of wear and breakage of the tools is prevented, and longer-lasting tools can be obtained. There are different surface treatment methods used for cutting edge preparation, such as brushing, laser machining and drag finishing [6]. Regardless of the process applied for surface finishing, the advantages of cutting edge preparation have been scientifically proven by many studies [7], [8].

The surface treatment method used in this study is the drag finishing method. In the drag finishing process, the cutting tools are fixed in the holders of the machine and dragged at high speed in a roational movement through the container filled with abrasive granules. The speed of the rotational movement creates a contact density between the cutting tool and the abrasive media. Finishing is done by removing chips from the cutting tool surface with contact density. In the literature, there are studies on speeds [9], time, immersion depth [10], and abrasive granules [11], which are factors affecting the finishing process. In a study [12], the relative motion between the workpiece and the abrasive media in drag finishing was modelled using the Discrete Element Method (DEM). In the study, the chip removal rate on the cutting tool is based on the contact density between the workpiece and the abrasive media. It is stated that the accuracy of the model is consistent with the experiments. As a result of the increased contact density between the cutting tool and the abrasive media, it is expected that the machining of the surfaces of tools with larger diameters will occur in a shorter time or at a higher rate. Is it really possible to machine larger diameter cutters in less time or at a higher rate in the same period? This study evaluates the finishing process and results of four different diameter milling cutters most commonly used in the machining industry.

2. Materials and Methods

The cemented carbide raw material with 10% Co content to be used in this study is UF10 grade raw material of IMC company and some of its properties are given in table 1.

Grade	Unit	UF10
ISO Range		K20-K50
WC + other carbides	%	90
Co	%	10
WC Grain Size		Submicron
Density	g/cm³	14.45

Table 1. Table example

The 4-flute end mills used in the study were produced on a 5-axis ANCA MX7 grinding machine. The cutting edges of carbide milling cutters manufactured in different diameters were improved with OTEC DF-3 drag finishing machine using OTEC HSC 1/300 abrasive granules. The abrasive material used in the study, HSC 1/300, is a mixture of 30% silicon carbide (SiC) with a grain diameter of dT ~ 200 µm and 70% walnut shell granules with a grain diameter of 0.8 mm ≤ dT ≤ 1.3 mm. The abrasive media of this mixture is suitable for the preparation of cutting edges of cutting tools made of cemented carbide [9].

Fig. 1. OTEC DF-3 Drag finishing machine.

The finishing parameters, which were used in experiment is shown in the Table 2.

Rotor speed [min^{-1}]	Holder speed [min^{-1}]	Immersion depth [mm]
50	80	430

Table 2. Finishing parameters

Fig. 2. Alicona Edgemaster

The milling cutters, whose cutting edges were prepared by drag finishing, were measured with the Alicona Edgemaster measuring device. For a better understanding of how the cutting edge radius and surface roughness are measured using 3D optical measurement, see the figure below.

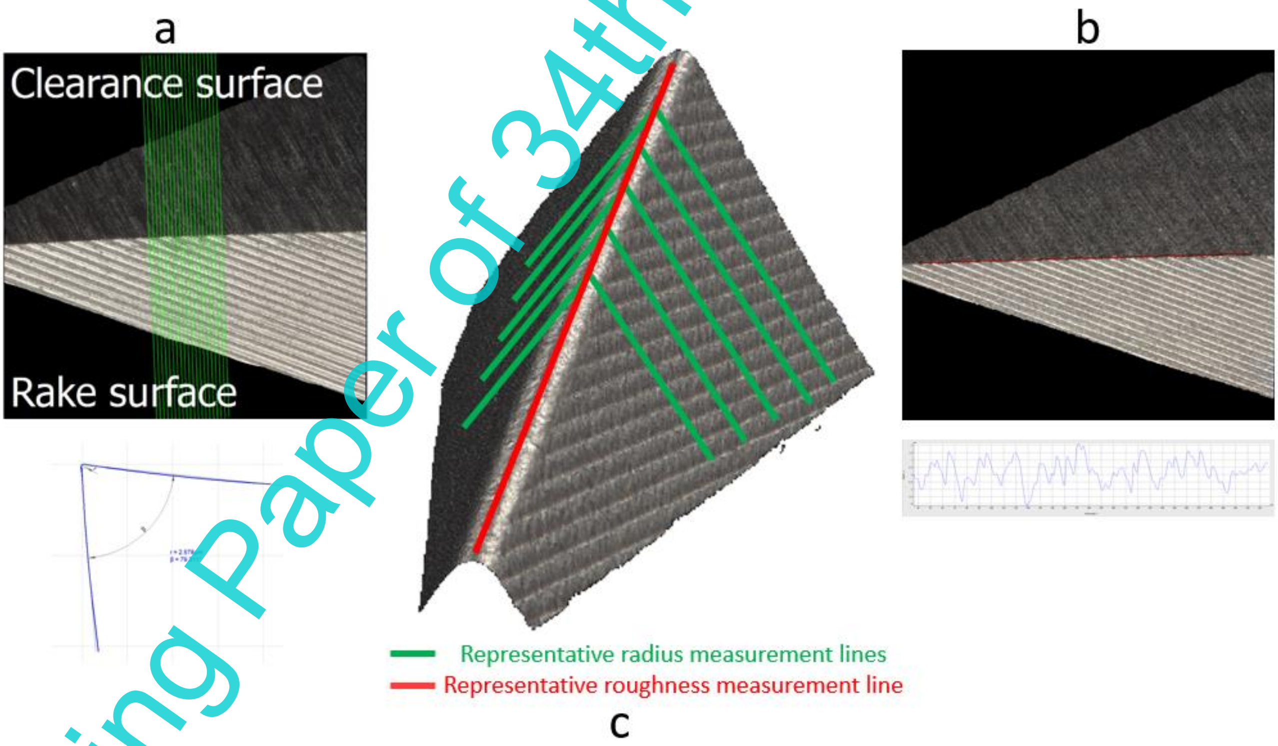

Fig. 3. Measurement lines

3. Results

In the experimental study, investigations are presented to analyse the effects of the drag finishing operation on solid carbide milling cutters manufactured in different diameters. For the investigations, carbide milling cutters with diameters of D=6, D=8, D=10, D=12 mm manufactured at TaeguTec Turkey were machined by drag finishing and the cutting edge rounding and surface roughness were analysed by means of 3D optical measurement.

HSC 1/300 granule, the content of which was previously specified, was used as abrasive media. The cutting edge rounding limit of this granule is ER=20 µm and the surface roughness processing limits are in the range of Ra=0.3-0.4 µm.

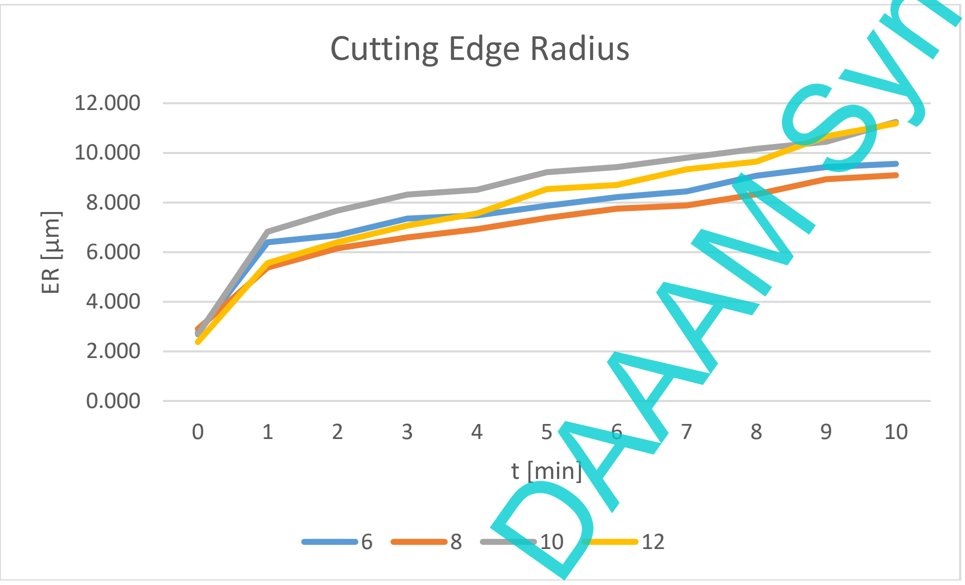

Fig. 4. Cutting edge radius, 10 minutes

The cutting edge radii of the milling cutters of different diameters after finishing are shown in Figure 4 for the first 10 minutes. The reason why this graph is given separately is to show the rapid change in the first minutes in more detail. Comparing Figures 4 and 5, it can be seen that the change observed in the first minutes is faster, while after a certain time the machining rate slows down. It can be seen that the cutting edges of the milling cutters with relatively larger diameters reach the rounding capability limit of the abrasive media, 20 µm, faster.

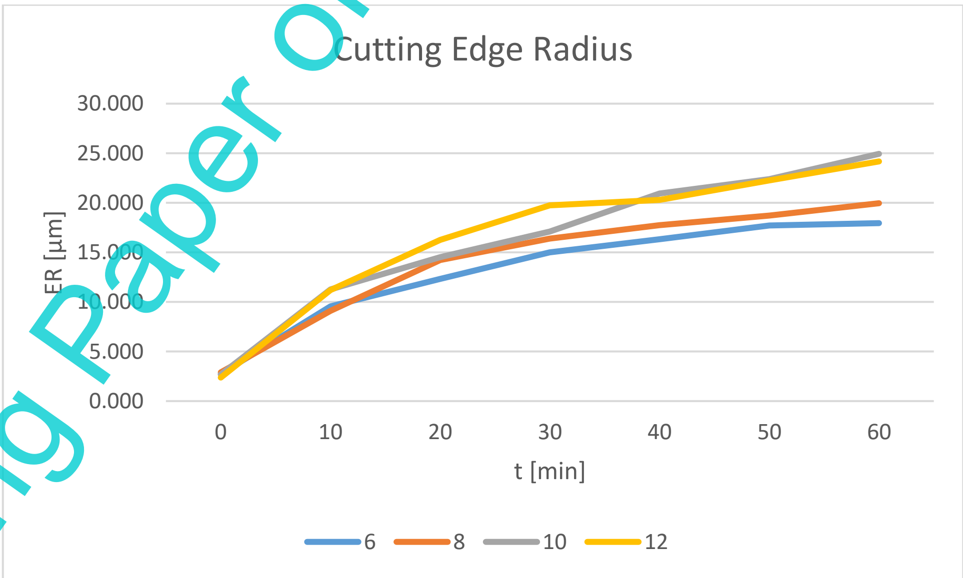

Fig. 5. Cutting edge radius, 60 minutes

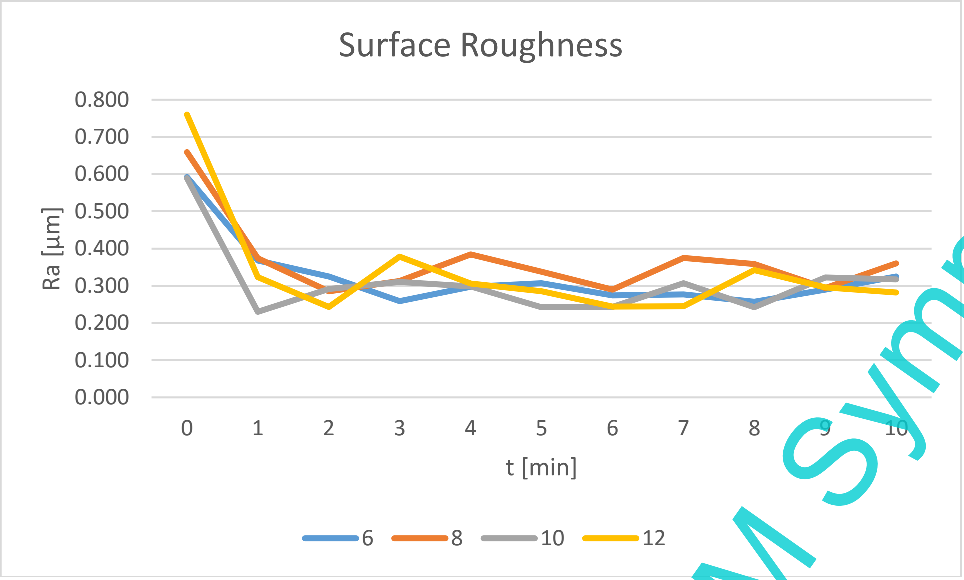

Fig. 6. Surface roughness, 10 minutes

In the graph in Fig. 6, which shows the roughness measurements in the first 10 minutes, it is seen that the change is faster in the first minutes, similar to the machining effect in the cutting edge radius graph. When the graph with longer measurements is analysed, it is seen that after 10 minutes, the change slows down and remains at 0.3-0.4 µm, which is the surface treatment limit.

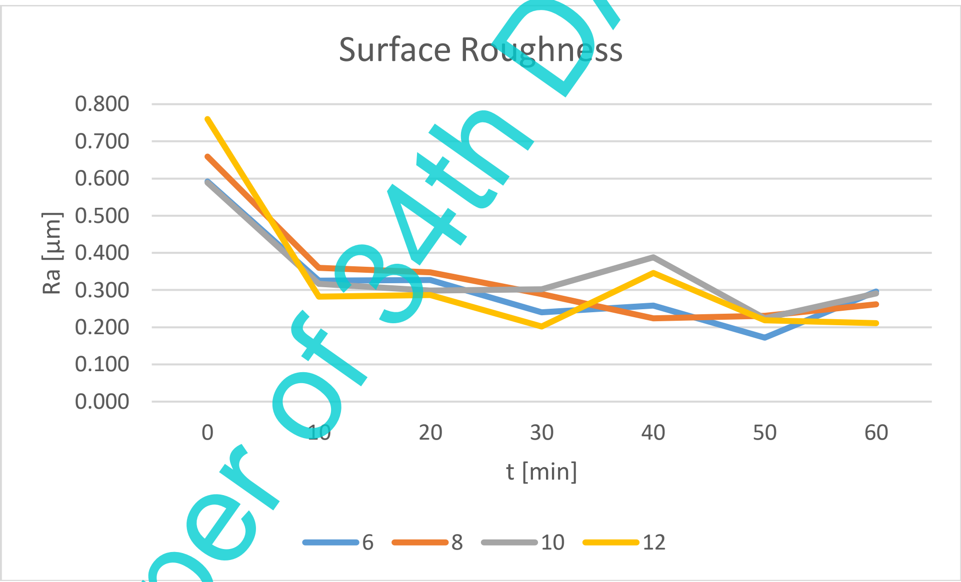

Fig. 7. Surface roughness, 60 minutes

Finally, below you can see the 3D image of a cutting edge before and after drag finishing.

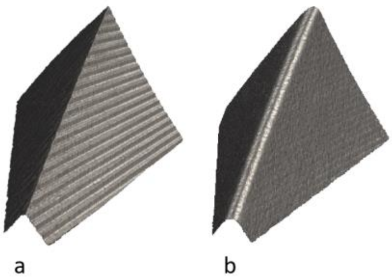

Fig. 8. a) Before drag finishing, b) After drag finishing

4. Conclusion

The focus of this study was to examine the effects of drag finishing on the cutting edge of a carbide milling cutter by performing 3D dimensional measurements. Therefore, an investigation was proposed in which carbide milling cutters of four different diameters would be machined on a drag finishing machine. 6, 8, 10, 12 mm diameter milling cutters with the same working parameters were machined on the drag finishing machine for surface treatment. After the drag finishing process, the differences between the cutting edges of the milling cutters of different diameters were determined. After a processing time of 60 minutes, the carbide milling cutter with a diameter of 6 mm could be rounded to approximately 18 µm. For 8 mm, this value was 20 µm, while the tools with 10 mm and 12 mm diameters exceeded 20 µm with the machining capability of the abrasive media. When the roughness measurements are examined, the improvement rate of the roughness in 10 mm and 12 mm milling cutters, which are larger diameters, is greater than that of 6 mm and 8 mm milling cutters. The reason for these two effects is that the contact density is higher due to the higher surface area of tools with higher diameters. The limitation of the study is that only HSC 1/300 abrasive media was used. In future studies, the results that can be obtained from different types of abrasive granules can be compared. When previous studies in which HSC 1/300 abrasive granules used in the study were examined, it was seen that the results took a shorter time to reach the limit value. The condition of the abrasive media, which has not been mentioned in any previous study, may have caused this result. After working for certain hours, the abrasive granules must either be replaced completely, or the machining feature must be maintained by renewing the volume at certain periods. For example, the machining ability of the abrasive media is higher in the first hours of operation and the surface processing times are shorter. However, since the abrasion properties of granules that have been used for a long time are lost, surface treatment times are longer. One of the most important points that manufacturers should pay attention to is continuity in quality. Therefore, it is more suitable to replace some part of the abrasive media volume in certain working periods to ensure process continuity by achieving the same cutting edge rounding rate and surface quality in the same period.

In future studies, the effects of different finishing methods or different finishing medias on cutting tools in drag finishing can be investigated. Research can be conducted to examine the effects of surface-improved milling tools on the machining performance or the surface quality of the workpiece.

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