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The effect of EUV modification of WC-Co indexable knives on the tool life during particleboard milling

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Abstract: *The effect of EUV modification of WC-Co indexable knives on the tool life during particleboard milling*. The paper presents the results of lifetime tests of WC-Co composite blades after modification of their flank surfaces using intense pulses of extreme ultraviolet (EUV). Wear tests consisting in milling a three-layer particleboard with constant cutting parameters were carried out on a CNC machining center. A statistically insignificant increase in the lifetime of modified tools was demonstrated, as well as an inversely proportional relationship with the duration of the EUV pulses. The EUV modification increased the coefficient of variation in the lifetime of WC-Co indexable knives.

Keywords: WC-Co indexable knives, EUV modification, tool life, particleboard, milling

INTRODUCTION

WC-Co is a basic cemented carbide used as a tool material in machining wood materials. In milling particleboards, the cemented carbide with a low content of cobalt (below 4%) and with submicron WC grains (below 1.0 μm) is used (Wilkowski et al. 2018). Due to the high hardness, this cemented carbide is resistant to friction wear, while its wear is due to the brittle fracture mechanism. Therefore, methods are being sought to improve the properties of cemented carbide as a result of modifying its surface layer.

The purpose of surface modification of tool materials is to improve their properties related to, among others, hardness, brittle cracking, coefficient of friction at the contact with the workpiece, or adhesion of wear resistance coatings. Various beam methods are used to modify the tool surface and include plasma (Bartnik et al. 2018, Fu et al. 2005, Samotugin et al. 2011, 2019), electron beam (Rakhadilov et al. 2017, Akao et al. 2014, Proskurovsky et al. 1998), ion implantation (Barlak et al. 2016, 2017, 2019, Fu et al. 2005, Wilkowski et al. 2018b, 2019, Wilkowski and Barlak 2019) or laser beam (Da Silva et al. 2013, Kołodziejczak et al. 2017, Wilkowski et al. 2017).

In this work, we describe an alternative method employed for surface modification, using intense pulses of extreme ultraviolet (EUV). Irradiation of material surface with the EUV radiation results in efficient ablation, changes of surface morphology and modification of the chemical structure (Bartnik et al. 2018). This method has not yet been studied in the context of surface modification of cutting tools, especially cemented carbides for machining of wood materials.

MATERIAL AND METHODS

WC-Co indexable knives with dimensions of 29.5×12.0×1.5 mm^3 in size, produced by Ceratizit company were used for tests (Fig. 1). The macro geometry of cutting edge is described

by wedge angle β = 55°. Selected properties of the tested WC-Co composites are shown in Table 1.

The clearance surface of WC-Co knives irradiated with a laser-plasma EUV source based on a double-stream gas-puff target, irradiated with the 3 ns/0.8 J Nd: YAG laser pulse at 10 Hz. The laser target was constructed by using nitrogen as working gas and xenon and helium as confining gases. Three variants of EUV pulse duration were used: 350, 400 and 500 μs.

Tab. 1. Properties of the tested WC-Co composites [www.ceratizit.com]

Material symbol	WC grain size [μm]	Binder content Co [%]	Density [g/cm^3]	Hardness	Bending strength [MPa]
KCR08	0.5-0.8	3.2	15.2	1790 (HV30)	2300

Three-layers particleboard produced by Pfleiderer with a thickness of 18 mm and density 648 kg/m^3 was subjected to machining tests. Workpieces with dimensions 1000×400×18 mm^3 were milled on CNC centre Busellato Jet 130 equipped with one edge milling head Faba FTS.07 with diameter 40 mm. There were made grooves (with a width equal to the tool diameter - 40 mm) in particleboard panels on a depth of 6 mm. During machining, constant cutting parameters (feed speed 2.7 m/s, spindle speed 18 000 rpm, feed per tooth 0.15 mm) were maintained. The maximum width of wear on clearance surface of blade (direct indicator VB_{max}) was measured with workshop microscope (Fig. 1). Machining was stopped as soon as the wear width was equal or higher than 0.2 mm. Thus, this value was assumed as tool wear criterion. Cutting length covered to achieve tool wear criterion (VB_{max} = 0.2 mm) was assumed as the tool life indicator (Wilkowski et al. 2017)

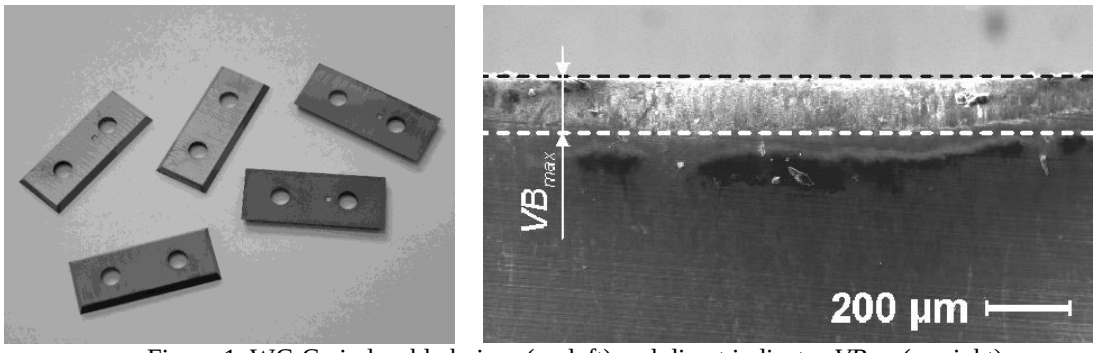

Figure 1. WC-Co indexable knives (on left) and direct indicator VB_{max} (on right)

RESULTS AND DISCUSSION

The EUV modification of the WC-Co clearance surface has increased the average cutting length from 1873 m for unmodified (control) knives to 2580 m for the knives modified with an EUV pulse of 350 μs. With an increase in duration of the EUV pulse, the average cutting length was reduced, and for a impulse of 500 μs, the average cutting length was 1969 m (Fig. 2).

Unfortunately, large fluctuations in the cutting length to obtain a tool wear VB_{max} = 0.2 mm indicated no statistical significance of differences between the tests.

The relative index of tool life referring to the total cutting length for virgin tools, for the best modification was 1.38, for the worst modification - 1.05 (Fig. 2, Tab. 2).

Virgin knives were characterized by a coefficient of variation of life-time equal to 0.29. Unfortunately, the modification process significantly increased this coefficient to a value over 0.40, regardless of the EUV pulse duration (Fig. 2).

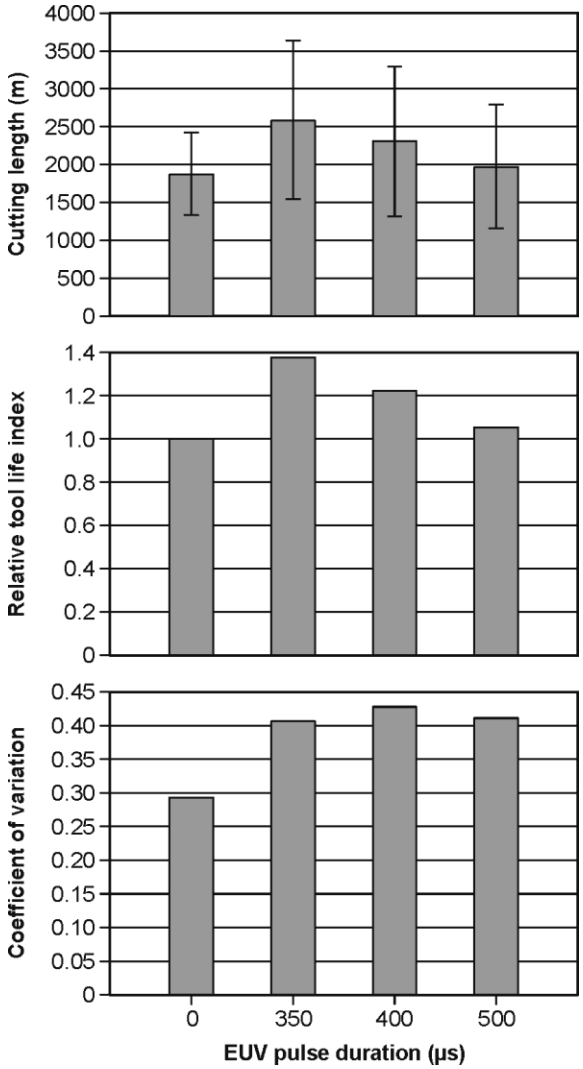

Figure 2. Relationship between EUV pulse duration and cutting length, relative tool life index and coefficient of variation of the tested WC-Co tools

In order to assess the quality of modifications, a tool life quality index was introduced, taking into account the relative index of tool life and the coefficient of variation of life-time, according to the formula:

$$QI = RI/CV \quad (1)$$

where: *QI* - the quality index of tool life, *RI* - the relative index of tool life, *CV* - the coefficient of variation of tool life. The relative index of tool life *RI* is ratio of average cutting length for modified tools to average cutting tools for unmodified (control) tools.

Of course, higher the *QI* value, the better the tools in terms of life-time and its variability. From the point of view of the use of tools in industry, it is not only the tool life expressed in terms of cutting time or cutting length to obtain the dulling criterion that is important, but perhaps more importantly, the life-time variability is also very important for the group of tools used. Tools with low life-time variability are suitable for use in automated machining systems requiring production planning and reducing its predictable costs in terms of tool life [Wilkowski et al. 2018b].

Table 2. The quality index of tool life

Index	Virgin	EUV 350 μm	EUV 400 μm	EUV 500 μm
RI	1.00	1.38	1.23	1.05
CV	0.29	0.41	0.43	0.41
QI	**3.40**	**3.38**	**2.86**	**2.55**

The quality index of tool life *QI* attained lower values (below 3.40) for all modifications regardless the duration of the EUV pulse compared to the value for virgin tools (Tab. 2). This means that the quality of these tools is lower, mainly due to a high variability of tool life *CV*.

CONCLUSION

According to the obtained results, one can formulate the following conclusions:

1. A statistically insignificant increase in the lifetime of modified tools was demonstrated, as well as an inversely proportional relationship with the duration of the EUV pulses.
2. The EUV modification increased the coefficient of variation in the lifetime of WC-Co indexable knives.
3. The quality index of tool life *QI* of the modified tools showed lower values than those of virgin tools, regardless of the EUV pulse duration.

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Streszczenie: *Wpływ modyfikacji EUV noży wymiennych WC-Co na ich trwałość podczas frezowania płyty wiórowej*. W artykule przedstawiono wyniki badań trwałościowych ostrzy z kompozytu WC-Co po modyfikacji ich powierzchni przyłożenia przy użyciu intensywnych impulsów promieniowania ultrafioletowego (EUV). Testy zużyciowe przeprowadzono na centrum obróbczym CNC podczas frezowania trójwarstwowej płyty wiórowej przy stałych parametrach skrawania. Wykazano nieistotny statystycznie przyrost trwałości ostrzy modyfikowanych, a także odwrotnie proporcjonalną zależność od czasu trwania impulsu EUV. Modyfikacja EUV zwiększała współczynnik zmienności trwałości ostrzy WC-Co.

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