

Comparative wear analysis of modified cutters during processing of milling of selected wood-based materials

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Abstract: *Comparative wear analysis of modified cutters during processing of milling of selected wood-based materials.* This study presents comparative investigations of durability of cutters covered with different variants of antiwear coatings. The impact of hard coatings spread on faces of cutters on the wear of cutting edges during the process of milling of chipboards and MDFs was investigated. Every time, the wear of the cutting edge caused by milling chipboards and MDFs was determined in the area of the same cutter utilising the entire length of the main milling edge which guaranteed the same characteristics of the applied coating. The edge wear surface area was measured using, for this purpose, a surface analyser. It was established that milling chip boards and MDFs of similar mean density using cutters made from high-speed steel covered with antiwear coatings of different characteristics caused, for each of the examined cutting edges, at least over 50 times greater wear during chipboard milling. The character of the obtained wear curves makes it possible to assume that the applied milling method will allow initial assessment of edge durability, especially in the case of MDF and will make it possible, on this basis, to plan the timetable of investigations.

Keywords: antiwear coatings, milling, cutting edge wear, chipboard, MDF

INTRODUCTION

At the present time, in the case of furniture industry, mainly such furniture board materials as chipboards and MDFs are used to manufacture constructions of furniture bodies. Elements exerting a decisive impact on both efficiency and quality of furniture body production include all factors from the so called WM/PO/T (woodworking machine – processed object - tool) system. The choice of the constituent elements of this system is a resultant of the production technology advancement. The factor that exerts a decisive impact on processing results is the condition and durability of the cutting edge. Many processing operations are carried out employing heads of different mounting systems of milling cutters. Cutters are most frequently manufactured from such materials of high-speed steel (HSS) and cemented carbide (HM). These materials are very popular and are characterised by defined possibilities regarding exploitation durability. Covering cutters with various antiwear coatings aims at increasing durability of cutter edges as well as improvement of the functional values regarding better milling results. Investigations in this field have been carried out by researchers for many years [3-5, 7].

Klimczyk et al. [2] reported that among possible ways of modification of composite coatings are multilayers composed of two or more layers manufactured from various materials and added that, in recent years, the interest in production of multilayers based on chromium nitride increased markedly. In their publication, Gilewicz et al. [1] concluded that tools with CrCN/CrN multilayer coatings improved the quality of the processed wood surface in comparison with cutters without coatings, while Szymański et al. [6], in their article, maintain that covering tools with hard antiwear multilayer CrCN/CrN-type coatings improves cutting edge durability during pinewood milling.

An important problem associated with investigations on durability of cutting edges in laboratory conditions is their time- and material consumption. Within the framework of the presented experiments, an attempt was made to accelerate the cycle of the cutting edge wear using HSS cutters covered with selected variants of composite coatings to mill chipboards and

MDFs and to obtain data regarding possibilities of utilisation of this kind of cutters for milling selected wood-based materials.

The objective of investigations was to compare durability of cutting edges of cutters for milling heads used for milling chipboards and MDFs. The experimental cutters were made from high-speed steel (HSS) with edges modified with four kinds of antiwear coatings of varying architecture.

RESEARCH METHODOLOGY

Investigations were performed on a bottom-spindle woodworking machine (Felder). Prior to the initiation of investigations, geometric and static accuracy of the woodworking machine was checked. During milling, the local device for chip removal was applied.

Investigations were conducted using 40x30x3 mm cutters (FABA), of 45° tool angle, manufactured from high-speed steel SW 18 onto which special antiwear coatings were applied. Cutters were mounted in a three-edge, cylinder mill head by means of clips.

A 16 mm thick MDF and a three-layer 12 mm thick chipboard were used in the performed experiments. Milling was carried out on specially prepared board panels 250 mm wide and 2 m long. Mean densities of experimental boards were as follows: MDF - ~740 kg/m³ and chipboard - ~785 kg/m³.

The designations of the experimental cutters with four variants of antiwear coatings were as follows: C1 cutter – a Cr₂N + CrN monolayer, C2 cutter – a CrN/CrN + TiAlN/TiAlN multilayer, DLC cutter – amorphous carbon and W-DLC cutter – a nanocomposite coating. The antiwear coatings were developed and spread on cutters at the Centre of Vacuum-Plasma Technology of the Institute of Mechatronics, Nanotechnology & Vacuum Technique of Koszalin University of Technology.

Narrow planes of both medium density and chip boards were milled with milling heights of $H = 16$ mm in the case of MDF and $H = 12$ mm of chipboard. The remaining parameters were as follow: thickness of the milled layer $h = 1$ mm, spindle rotational speed - $n = 6000 \text{ min}^{-1}$, feed speed - $v_f = 6.3 \text{ m} \cdot \text{min}^{-1}$ (three-rolled Felder feed device was applied), milling speed - $v_c = 35.8 \text{ m} \cdot \text{s}^{-1}$ and feed per cutting edge - $p_z = 1.05$ mm.

Milling investigations on both the MDF and chip boards were conducted using the same cutters utilising optimally the entire length of the upper milling edge. This research approach allowed unequivocal comparative reference to the characteristics and architecture of the applied antiwear coatings.

Cutting edge wear measurements were carried out on a modernised surface analyser ME10 (Carl Zeiss Jena) workstation. Utilisation of this profilograph made it possible to obtain high measurement density on the entire area of the cutting edge. A special measuring stylus of 25 µm rounding radius and 3 mm length of the measuring edge as well as a µDAQ-Lite measuring module were employed which were coupled with a PC and special software. Cutters were mounted in a repeatable manner in a specially designed grip. The registered wear profiles were recorded as ASCII files. The employed software allowed comparison of diagrams from different stages of investigations and calculation of areas of the cutting edges.

RESULTS AND DISCUSSION

Table 1 presents types and characteristics of coatings applied onto cutting edges of cutters used in the described investigations.

Table 1. Types and characteristics of antiwear coatings used in experiments

Cutter	C1	C2	DLC	W-DLC
Type of coating	monolayer	multilayer	amorphous	nanocomposite
Coating composition	Cr ₂ N+CrN	CrN/CrN+TiAlN/TiAlN	amorphous carbon	Nanocrystalline separations of wolfram carbides (WC) in amorphous matrix of hydrogenated carbon (a - C : H)
Coating thickness [μm]	2.38	3.43	1.8	2.9
Coating hardness[GPa]	24	18	41	19.3
Surface roughness Ra [μm]	0.1	0.33	0.2	0.06

Figure 1 shows calotest friction track of the selected C1 and C2 coatings of applied onto cutters used in experiments.

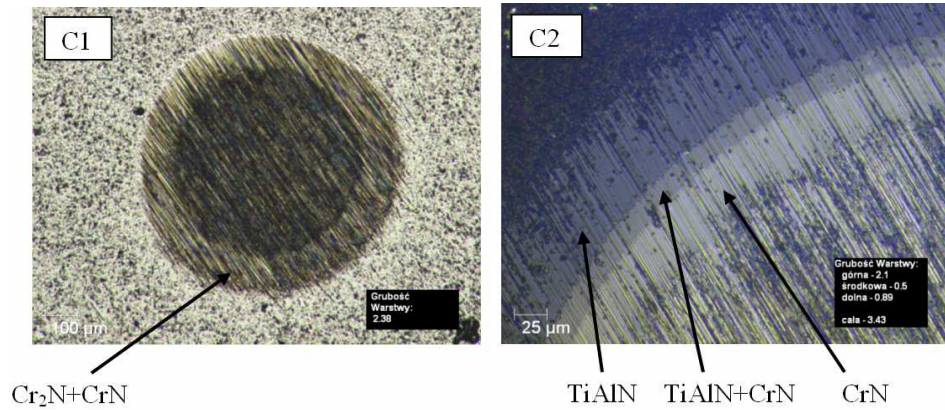


Fig. 1. Calotest friction track of the C1 and C2 coatings

The diagram (Fig. 2) presents research results of cutters cutting edge wear covered with different combinations of antiwear coatings applied in the discussed experiments depending on the milling distance in the course of milling of MDF and chip boards.

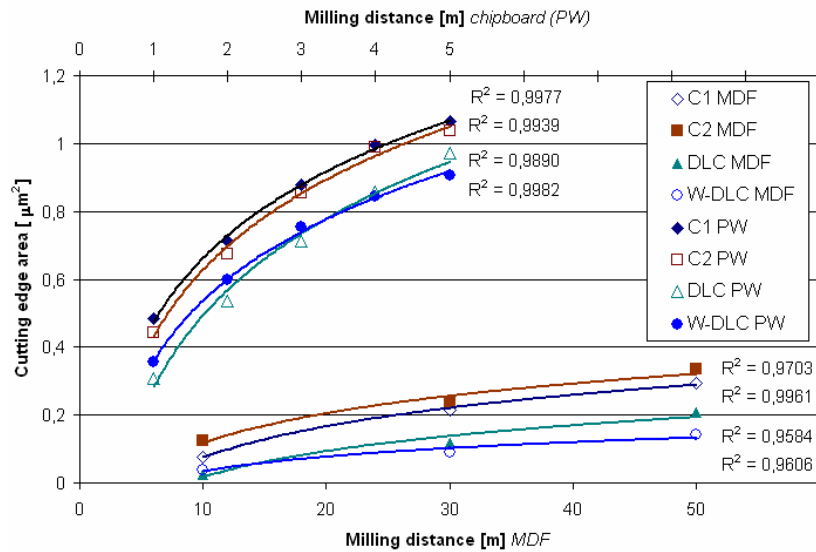


Fig. 2. Dependence of the cutting edge area in the milling distance function for cutters with different architecture of antiwear coatings during milling of MDF and chipboard

The presented diagram (Fig. 2) shows a distinctly greater wear of all the examined cutting edges from high-speed steel covered with different antiwear coatings in the course of milling of the experimental chipboard than of the MDF. Both the chipboard as well as the MDF were milled using the same cutting edge utilising the entire length of the main milling edge (Fig. 3). The observed wear areas of the examined cutting edges show that, in the case of chipboard processing, the wear of each of the examined cutting edges was distinctly greater (at least by more than 50 times) in comparison with the milling of the MDF. The performed analysis of edge durability (Fig. 2) makes it possible to conclude that the best results were obtained for the cutting edge of the W-DLC cutter with the nanocomposite coating and for the cutting edge of the DLC cutter with the amorphous coating, both in the course of MDF and chipboard milling.

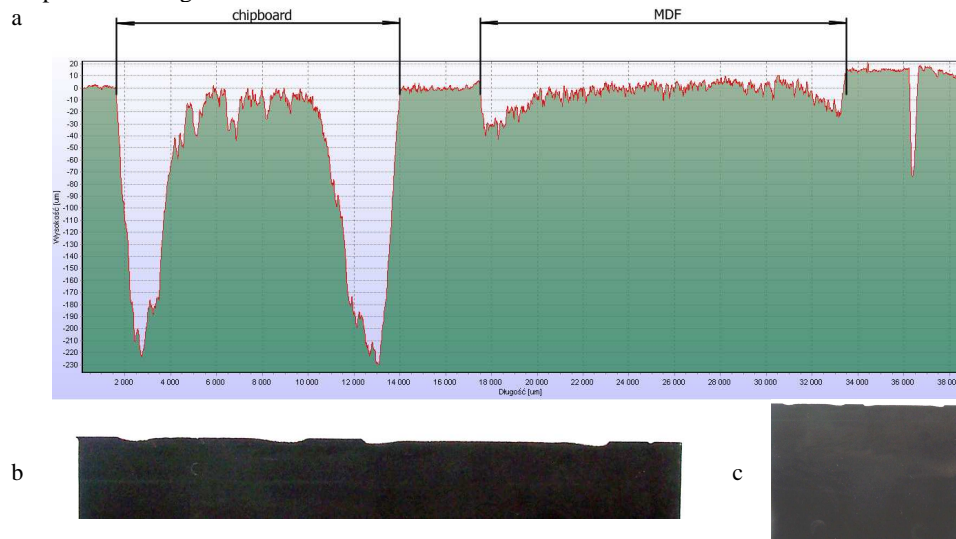


Fig. 3. Wear images of cutting edges of the DLC cutter: left side – chipboard (5 m); right side – MDF (50 m); a – wear profilogram, b – cutting edge of a cutter, c – general view of the cutter

CONCLUSIONS

The milling of chipboards and MDF of similar mean densities with cutting edges of high-speed steel covered with antiwear coatings of different characteristics and architecture caused, in the case of each of the examined edges, over 50 times greater wear in the course of chipboard milling.

The comparison of cutting edges of the experimental cutters made of high-speed steel and modified using four different variants of antiwear coatings used in this investigation revealed that the W-DLC cutter with a nanocomposite coating was characterised by the best durability during machining of the chipboard and MDF.

The character of the obtained individual wear curves made it possible to conclude that the applied method of milling of wood-based materials using cutting edges of high speed steel covered with antiwear coatings of different structure will accelerate, especially in the case of MDF, the initial assessment of durability of cutting edges and facilitate planning of research timetable on this basis.

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Streszczenie: *Analiza porównawcza zużycia ostrzy modyfikowanych podczas obróbki wybranych tworzyw drzewnych.* W pracy przedstawiono badania porównawcze trwałości ostrzy pokrytych różnymi wariantami powłok przeciwzużyciowych. Badano wpływ twardych powłok nakładanych na powierzchnie natarcia noży, na zużycie ostrzy, w czasie frezowania płyty wiórowej i płyty MDF. Zużycie ostrza, wynikające z frezowania płyty wiórowej i płyty MDF, określano każdorazowo w obszarze tego samego noża, wykorzystując całą długość głównej krawędzi skrawającej, co gwarantowało taką samą charakterystykę nałożonej powłoki. Mierzono pole powierzchni zużycia ostrza z zastosowaniem profilografometru. Ustalono, że frezowanie płyty wiórowej i płyty MDF, o przybliżonej średniej gęstości, nożami ze stali szybko tnącej, z naniesionymi powłokami przeciwzużyciowymi, o różnej charakterystyce, powoduje, dla każdego badanego ostrza, co najmniej ponad 50 krotnie większe zużycie podczas skrawania płyty wiórowej. Charakter otrzymanych krzywych zużycia, pozwala sądzić, że zastosowana metoda frezowania umożliwi, w przyspieszony sposób, szczególnie z zastosowaniem płyty MDF, ocenić wstępną trwałość ostrzy i na tej podstawie planować harmonogram badań.

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