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Wear of cemented carbide cutters after milling of MDF boards

GRZEGORZ PINKOWSKI[1)], WALDEMAR SZYMAŃSKI[1)], ADAM GILEWICZ[2)], MACIEJ SYDOR[1)]
[1)]Department of Woodworking Machinery and Fundamentals of Machine Construction, Poznań University of Life Sciences
[2)]Institute of Mechatronics, Nanotechnology & Vacuum Technique, Koszalin University of Technology

Abstract: *Wear of cemented carbide cutters after milling of MDF boards*. The paper presented results of tests on blade wear in cutters made from HM cemented carbides. Tests consisted in milling of single side laminated MDF boards. Machining was performed on a CNC machine board using an inserted-tooth shank cutter. Three types of cutters were tested, one with a coating based on chromium nitride CrCN/CrN, one with a coating based on titanium alumninium nitride TiAlN/TiN and one without coating. Blade wear was determined by measurement of the edge loss recorded from the side of the cutter tooth face. The surface area of blade loss in 14 measurement points was recorded for cutting distance of 2 to 630 m. Testing results indicate a lesser wear in the cutter with the coating based on chromium nitride CrCN/CrN in relation to the cutter without coating, while the wear of the cutter with the coating based on titanium aluminium nitride TiAlN/TiN was comparable to that of the cutter without coating.

Keywords: wear, milling, MDF, antiwear coatings

INTRODUCTION

The furniture industry uses a highly diverse range of raw materials, from solid wood of commercially available wood species to wood-based materials differing greatly in terms of their properties and prices. The MDF board as a wood-based material has a large variety of practical uses, a homogeneous composition and more uniform density than e.g. particle boards. Laminated MDF panels are used in the furniture industry most commonly to produce furniture fronts.

Among element forming technologies a major role is played by machining. Since the very beginning of this technology the primary objective has been to achieve the highest possible efficiency, while improving or at least maintaining machining accuracy and face layer quality of machined products (***Djouadi et al. 2000***). This may be easily attained using the currently available computer numerical control (CNC) machine tools. They are highly efficient machine tools, while their definite advantage is connected with the possibility to perform many machining operations within one cycle without the need to remount the machined element. In this way machining time may be considerably reduced in comparison to traditional machine tools.

In modern CNC machine tools milling is a basic machining method used both on wood-based materials and solid wood. This type of machining is performed using e.g. shank cutters with extensive uses. Each tool used in the cutting process undergoes wear. It may consist e.g. in changes in its geometry, most frequently connected with material loss, changes in properties related with deformations, temperature, chemical action of the cutting agent, etc. (***Cichosz 2006***).

The problem of blade wear is crucial from the point of view of quality of machined surface as well as blade wear rate, affecting a total balance of production costs. High machining costs of materials resulting from a rapid tool wear are the reason for the continuous research on new tool materials and their modification. One of the methods to limit wear is provided by special modification of the surface layer of cutting tool blades or coating these blades with thin hard coats, primarily compounds of carbon, nitrogen and boron with transition metals, or coats of superhard materials (***Gilewicz et al. 2010, Kupczyk 2008***).

Presently coatings are applied on blades made from practically all tool materials, even on blades from superhard materials. Coating materials vary in their properties, advantageous thanks to their effect on cutting and performance properties of blades (***Cichosz 2006***).

Extensive research is also currently being conducted on the modification of machining tools for wood and wood-based materials using antiwear coatings (***Djouadi et al. 2000***, ***Faga et al. 2006, Nouveau et al. 2005, Szymański et al. 2009, Warcholiński et al. 2009***).

The aim of this study was to determine wear of cutters made from cemented carbide HM covered with two types of antiwear coatings, one based on chromium nitride and one based on titanium aluminium nitride, and to compare their wear to that of a cutter without coating.

METHODOLOGY

The tests were conducted on cutters made from cemented carbide HM, commercially available as SMG02. A total of three blades were tested, one without antiwear coating and two covered with different coatings. Denotations and the type of cutter coatings are presented in Table 1. Cutter dimensions were 30x12x1.5 mm, while blade angle was 55 degrees.

Tab. 1 Denotations and characteristics of tested blades

Cutter denotation	**Type of antiwear coating**
Cutter I	without coating
Cutter II	coating based on chromium nitride CrCN/CrN
Cutter III	coating based on titanium aluminium nitride TiAlN/TiN

Antiwear coatings applied on the tested cutter blades were applied by cathode arc deposition in the atmosphere of nitrogen or nitrogen and acetylene. Coating based on chromium nitride is a multi-layer coating, formed of 6 CrCN/CrN modules. Each of them is approx. 400 nm thick and is a reproducible double layer. Each module is formed of two monolayer coatings. One of the module monolayers is formed from chromium carbonitride (CrCN), while the other is based on chromium nitride (CrN). In each module the proportions of thicknesses for individual monolayers are identical, at a CrCN : CrN ratio of 1:2. Jointly for the entire coating all the 6 modules are approx. 2.5 μm thick.

Coating based on titanium aluminium nitride is composed of three layers. The last coating was composed of a double layer TiAlN/TiN coating and a transition TiAlN $\Rightarrow$ TiN layer. Thickness of the first layer was 1.25 μm for TiAlN, for the second layer it was 0.5 μm and for the transition TiAlN $\Rightarrow$ TiN layer, while for the third TiN layer it was 0.75 μm. Thickness of the final coating ranged from 2.4 to 2.5 μm.

Both types of coating were applied onto the tested cutters at the Centre of Vacuous-Plasma Technology of the Institute of Mechatronics, Nanotechnology & Vacuum Technique of the Koszalin University of Technology.

The cutting process was performed on a triaxial CNC type FLA-16CNC milling machine. During machining tests identical machining parameters were maintained for all samples, guaranteeing comparability of recorded results. Rotational speed of 18000 min^{-1}, feed rate of 5 $m \cdot min^{-1}$, cutting diameter of 16 mm, height of machined layer of 1 mm, one cutting blade and tool rake angle of 20 degrees were applied.

Tested material was single sided laminated MDF board. Board thickness was 16 mm, while its moisture content was 5.25%.

The tool used for analyses was a shank cutter, in which replaceable blades were mounted. Balancing of a tool with one cutting blade is ensured by the mounting of a second properly prepared blade, which would balance the cutting blade and which would not participate in machining.

Tool wear was measured on a testing station composed of a modified Carl Zeiss ME10 profilometer and specially developed software for blade wear analysis.

In blade wear tests the profilometer was equipped with a gauge bar in the form of a skid, with edge length of 3 mm, corner radius of 25 μm and angle of 20 degrees.

Wear area was measured from the side of the cutter tooth face. The primary unfiltered profile of the main cutting edge was recorded. Recording parameters were constant for all analysed cutters. The feed rate of the gauge bar was 100 μm/s and discretisation step was established at 10 μm.

The condition of the main cutting edge was evaluated for all cutters at identical measurement points, i.e. after cutting of 0, 2, 50, 100, 150, 200, 225, 270, 360, 405, 450, 495, 540, 585 and 630 running metres of material.

Recorded data were further processed, consisting in the levelling of the profile and matching of the profile obtained after a specific cutting distance to the zero profile. Profile matching was performed on the main cutting edge outside the cutting zone and only after they were matched the wear area of the blade was calculated.

In Fig. 1 the green line (1) marks the profile of the cutting edge for a new blade, with zero cutting run, while the red line (2) marks the profile of the edge at one of the above mentioned measurement points. Wear was automatically calculated as the surface area (3) formed between the overlapping and fitted graphs. Values plotted on axes in Fig. 1 are expressed in μm. The position of the cutter in relation to the profilometer skid during wear area testing is presented in Fig. 2.

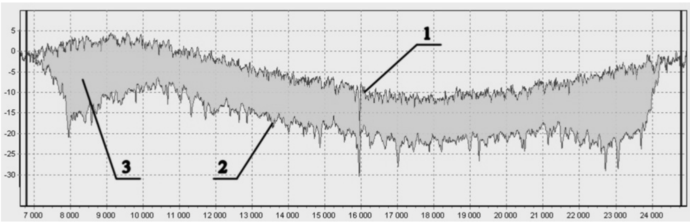

Fig. 1 A scheme for tool wear measurement: 1 – the profile of cutting edge of a sharp cutter with zero cutting distance, 2 – the profile of cutting edge of a cutter with the analysed cutting distance, 3 – blade wear area

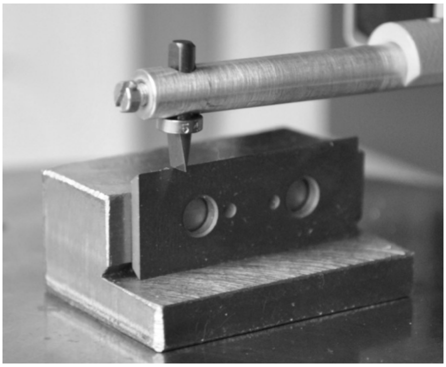

Fig. 2 The position of a cutter in relation to the profilometer skid during wear area testing

RESULTS

Figure 3 presents selected graphs of wear area for two analysed cutters. This Figure shows wear at the cutting distance of 100, 270, 405 and 630 m. On the left the Figure presents wear areas for cutter I, i.e. without antiwear coating, while on the right it is for cutter II, i.e. with the coating based on chromium nitride.

In this Figure we can see a gradual increase in wear areas with an increase in cutting distance. It is particularly evident for cutter I (without coating). Wear area of cutter II after identical cutting distance is much smaller.

It needs to be observed here that cutter wear is much greater at outer MDF layers than its core. This dependence resulted from the varied board density at the cross-section. Board density in the centre is lower and at the outer layers it is much greater. The laminate layer also has a marked effect on cutter wear, as evidenced on the left of the cutter wear area.

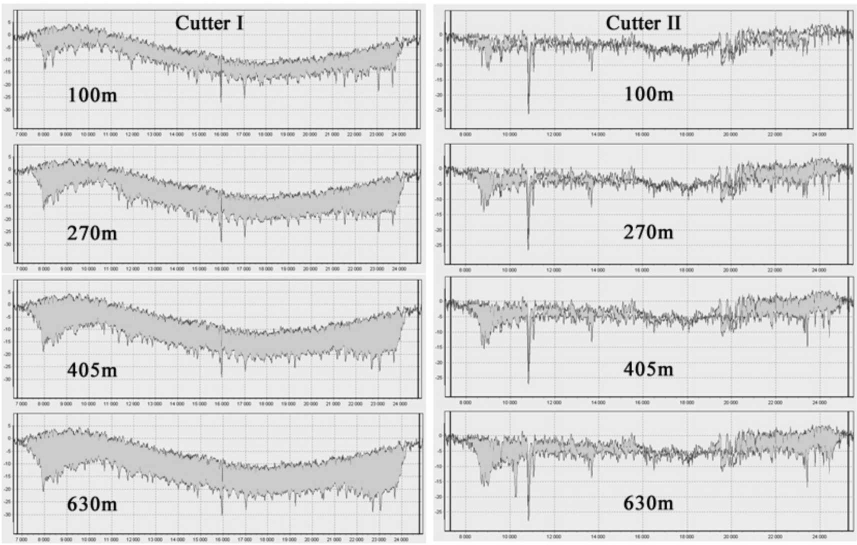

Fig. 3 Graphic presentation of wear areas for cutters I and II for cutting distances of 100, 270, 405 and 630m

Figure 4 presents a dependence between cutter wear area and cutting distance. This dependence indicates an increase in cutter wear with an increase in cutting distance, while initially (up to approx. 100 m) the increase in wear is more intensive.

Curves of wear presented in Fig. 4 show that cutter II with the coating based on chromium nitride CrCN/CrN for the analysed cutting distance had the smallest wear among all the tested cutters. The value of this wear was markedly lower than for cutter I, i.e. that without antiwear coating. Cutter III with the coating based on titanium aluminium nitride TiAlN /TiN for the investigated cutting distance showed a comparable wear to that of the cutter without coating.

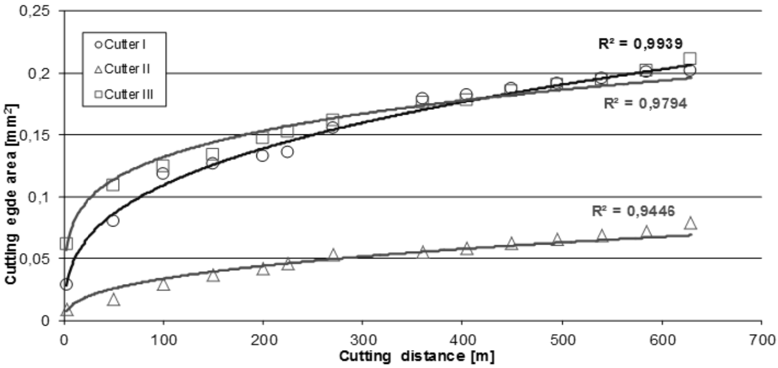

Fig. 4 Dependence of cutting edge area in the cutting distance function for all cutters during milling of MDF

CONCLUSIONS

1. The distribution of blade wear over the length of the cutting edge is non-uniform. Increased wear was observed on areas of greater density of the machined material. It was greatest for the zone, in which laminated material layer was cut.
2. For all the analysed cutters blade wear increased with an increase in cutting distance.
3. Cutter II with coating based on chromium nitride CrCN/CrN for the covered cutting distance showed the least wear. The value of this wear was approx. 2.5 lower than for cutter I without antiwear coating, while cutter III with coating based on titanium aluminium nitride TiAlN /TiN for the covered cutting distance exhibited wear comparable to the uncoated cutter.
4. All the analysed cutters showed the greatest growth dynamics for blade wear in the initial phase of the cutting process. At later stages of the process the wear dynamics for all tested blades decreased markedly.

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Streszczenie: *Zużycie noży z węglika spiekanego po frezowaniu płyt MDF*. Praca przedstawia wyniki badań zużycia ostrzy noży wykonanych z węglików spiekanych HM. W badaniach frezowano płyty MDF jednostronnie laminowane. Obróbkę przeprowadzono na obrabiarce CNC z zastosowaniem frezu trzpieniowego z nożami wstawnymi. Badano trzy rodzaje noży, jeden z powłoką na bazie azotku chromu CrCN/CrN, drugi z powłoką na bazie azotku tytanowo-aluminiowego TiAlN/TiN oraz trzeci bez powłoki. Zużycie ostrza określono poprzez pomiar ubytku krawędzi mierzony od strony powierzchni natarcia. Wyznaczono pola powierzchni ubytku noży w 14 punktach pomiarowych w zakresie drogi skrawania od 2 do 630m. Uzyskane wyniki badań wskazują na mniejsze zużycie noży z powłokami na bazie azotku chromu CrCN/CrN w stosunku do noża bez powłoki, natomiast zużycie noża z powłoką na bazie azotku tytanowo-aluminiowego TiAlN/TiN było porównywalne do zużycia noża bez powłoki.

Author's addresses:

Grzegorz Pinkowski, Waldemar Szymański, Maciej Sydor
Department of Woodworking Machinery and Fundamentals of Machine Construction,
Poznań University of Life Sciences,
ul. Wojska Polskiego 38/42,
60-627 Poznań, Poland
e-mail: GPinkowski@up.poznan.pl
e-mail: WSzymański@up.poznan.pl

Adam Gilewicz
Institute of Mechatronics, Nanotechnology & Vacuum Technique,
Koszalin University of Technology
Racławicka 15-17
75-620 Koszalin