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Wear of Special Treated Tools During MDF Peeling

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Abstract- Tools with chromium nitride coating applied by triode pulverizing have been tested in routing and peeling of wood. The efficiency of coatings was proved in medium density fiberboard cutting, thus in heavy cutting conditions , as well as in routing of OSB (Oriented Strand Board) where a CrN coating of 1µm of thickness allowed to process up to 9 times longer than in case of non-dressed tool [1].

The purpose of this study was to examine the improvement of the tools wear in the peeling of MDF, achieved by special treatment of the tool. The modifications of the active surfaces of knives by applying hard coatings (CrAlN, CrSiN), have already given the promising results in the routing of the MDF [2]. The limiting factor of applying these coatings is their adhesion to the substrate –the cutting tool. For this reason the duplex treatments including nitriding and hard coating deposition were tested

Nitriding treatments have been performed inside a low vacuum furnace equipped with an impulsive current generator. The CrAlN coating was carried out by a dual magnetron sputtering system 8NORDIKO type 3500-1356 MHz.

The CrSiN films were deposited using DC/RF dual magnetron sputtering system (AC450). In order to study the Si content effect on the CrSiN properties, two targets (50.8 mm of diameter) of Cr (99.99%) and Si (99.99%) were used. ADC and RF (13.56 MHz) generator were used to polarize the Cr and Si targets, respectively. The Cr target/substrate distance was 80mm while the Si target/substrate distance was only 70mm.

The CrSiN coating have been prepared by institute FEMTO/ST of Besancon.

The wood machining tests were performed using a laboratory microlathe which permits to make a simulation of the peeling process.

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. Introduction

Modification of metal-cutting tools surfaces, which involves covering them with materials of increased abrasive resistance, improves their lifespan [3]. All attempts to employ antiabrasive materials, applied with good results in metal cutting, in wood cutting are farcing important difficulties caused by differences in physical and chemical structures between wood and metals [4,5]. One of the major problems concerning wood cutting tools is the occurrence of nicks on the cutting edge mainly due to the impact of knots, or foreign bodies that green wood frequently contains. This phenomenon is accentuated by a small tool angle often used in the wood machining tools. In the peeling process, two situations may occur: first, when the dimensions of the nicks are less than 200µm depth, the operator must intervene with pumice in order to sharpen the damaged area. In this case, production is not affected [3].

Second, if the edge is totally broken (size of nicks exceeds 1mm of depth), a change of tools is necessary. These repeated stops induce economic losses and harder working conditions for the operators. Previous studies showed the effectiveness of surface coatings such as hard layers obtained by PVD methods (TiN, CrN, etc.) or surface treatments such as nitriding and duplex treatments against wear in wood machining and especially in peeling [1 – 5].

The low cutting angle (19 – 22◦) is the main problem and is responsible for significant abrasive wear of the tool during its running time.

However, the applications of the hard coatings are limited by their low adhesion to the majority of substrates. In previous studies revealed that beyond 200 nm of thickness, the film delaminates automatically [6].

Some works were led to improve this adhesion by the heating of the substrate [6, 7] or by the realization of sublayers between the substrate and the film [8, 9]. In our study we include the nitriding treatment to improve the adhesion of the coatings.

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II. Materials and Methods

A. Cutting tools

The cutting tools were made of 90CrMoV8 (“La Forézienne- MFLS”, France trademark) steel (Table 1) currently used in the peeling process. The geometry of the tools is represented in Fig. 1.

The cutting edge was polished to obtain a *R*a = 0.2–0.5 µm and an *R*t =1µm with SiC disks (N°. 180). Before the deposition, the cutting tools were ultrasonically cleaned with alcohol and *in situ* etched under an argon ion bombardment for 5 min.

Table.1: Composition (%) and hardness of 90CrMV8

Fe	C	Si	Mn	Cr	Mo	V	HRc
88	0.5	1	0.5	8	1.5	0.5	54-56

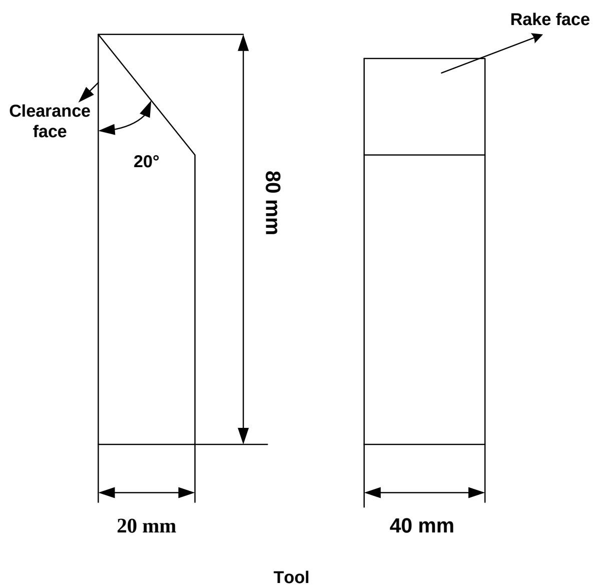

fig.1: Geometry of a micro-peeling tool

B. Treatment of plasma nitriding

Nitriding treatments have been carried inside a low vacuum furnace (4500*450*450) equipped with an impulsive current generator fig2. The temperature of the samples was monitored with a thermocouple located just next to them.

The type of nitriding layers and theirs qualities depend of the gas mixture, the pressure and the time of nitriding process [10]. So the nitriding conditions were fixed as follows 12h at 500° C, mixture of gas: 20% N_2 + 80% H_2, steel material 90CrMoV8. This tool material was chosen because it contains sufficient amount of Cr, Mo and V, necessary for an effective nitriding.

Fig.2: Plasma Nitriding System (BMI)

C. Coatings deposition

CrN and CrAlN coatings were deposited using an RF dual magnetron sputtering system (NORDIKO type 3500-13.56 MHz) fig.3. The deposition were conducted with use of two pure targets Cr (99.995%) and Al (99.999%) (101.6 mm of diameter and 3 mm thick). The targets/substrates distance was 90 mm. The layers were deposited on the rake face of cutting following the report of Nouveau [1].

Table 2 summarizes the depositions conditions.

fig.2: Dual Magnetron Sputtering System

Table.2: Deposition conditions of the CrN, CrAlN and CrSiN coatings

Coating	Working pressure (µbar)	Cr bias (-V)	Al bias (-V)	Si bias (-V)	Deposition time (mn)
CrN	4	900	0		90
CrAlN			300		
CrSiN	4	380		180	105

D. Peeling process

All of prepared tools were tested in machining by MDF (Medium Density Fiberboard) peeling on the laboratory mircolathe equipped with force sensors. The MDF boards - highly abrasive material was cut into disks as shown in Fig. 3A. The micro-peeling process and the forces that occur during the machining are represented in Fig. 3B (especially *F*Xc and *F*Yc forces).

The cutting parameters were constant during all the peeling operations: linear cutting speed - 0.5 m/s; clearance angle - 3°; veneer thickness - 0.3 mm.

The recession of the cutting edge representing the tool wear was observed and measured using the calibrated optical microscope (OM-Olympus Vanox-T AH-2), as shown in Fig4.

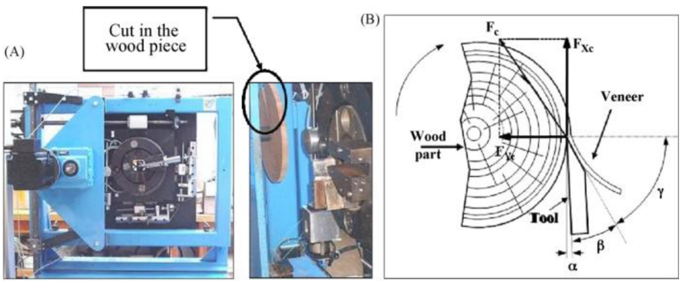

Fig.3: Micro-peeling system (A) and peeling process with the forces applied during the tests (B).

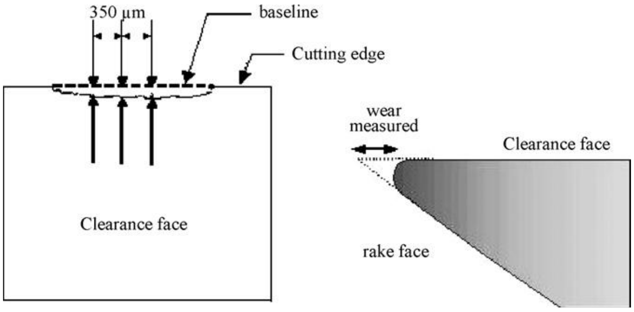

Fig.4: Measurement of the reduction of the micro-peeling knives cutting edge.

III. Results and Discussion

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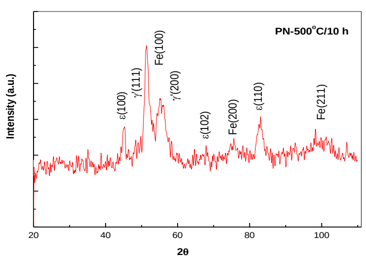
A. X-Ray Diffraction (XRD) analysis

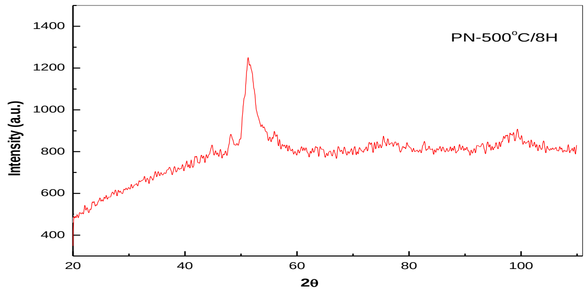
XRD analysis of an unnitrided steel along with post nitrided steel have been made for all the samples with various treatment conditions. The X-ray diffraction anhad been performed with Co-k_α target. Among the various treatment conditions carefully selected samples have been chosen for the structural characterization. Following are the X-ray patterns revealed after 500°C treatment for 8, 10, 12 h exposure time. These patterns have been chosen here to represent the typical phases formed after the nitriding treatment. A careful observation of these patterns leads to the conclusion that the iron (Fe) peaks are widening and also shifting to the left, by nitriding. This confirmes the fact thatthe nitrogen gets into the solid solution and generates the stress. Also it may be understood that the increase in treatment time is beneficial in producing the nitrides and also its growth fig 5. Thus the treatment time plays the important role. The nitrides produced in this study are epsilon and gamma-prime. With the increase in the treatment time the signature of epsilon phase becomes more dominant what stands for higher technical value e.g. corrosion resistance.

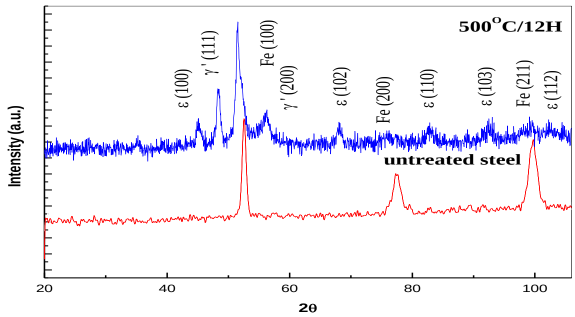


(a)

IV.

(b)



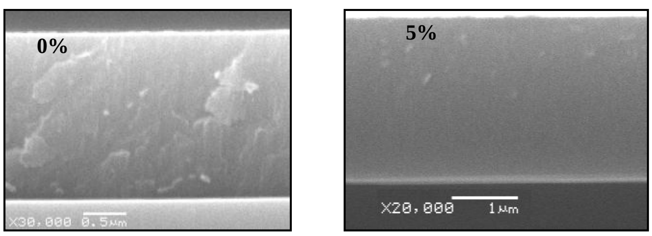


(c)

fig.5:X-ray diffractogram of 90CrMoV8 steel; (a) in as-received condition and after nitriding at 500°C for 8h and (b) after nitriding at 500°C for 10 h and (c) for 12 h.

A. Scanning eEectron Microscopy (SEM), analyse of the CrAlN and CrN films

The observations of the layers morphology was carried out by SEM on silicon coated samples then cleaved with a diamond tip. The figure 6 shows clearly the CrN film structure is dense and amorphous. Aluminum (Al) addition causes the films to have a dense, but columnar structure. This structure is not clearly visible at 5% of Al, but with the increase of Aluminum percentage the columnar structure becomes more visible [2].



(a) (b)

fig.6: SEM cross–section observations of the (a) CrN and (b) CrAlN films

B. Application in peeling of MDF

First, the wear resistance of the tools with different treatments was tested while the forces of cutting were observed. Then, the quality of these tools was determined. In the next phase the shock resistance of the tools was verified.

C. Microlathe abrasion tests of MDF

Six different tools were tested in machining: untreated tool, CrSiN-coated tool, CrAlN-coated tool with 5% of Al, CrN-coated tool, duplex treated (nitriding + CrAlN) tool and a nitrided tool.
The results are summarized in Fig. 7. From the figure 7 it is clear that the first 200m of machining, shows well the durability of the tool: if a tool performed well during this period, it will have good results at the end of the test. On the other hand, the CrSiN coated tool has revealed the best wear performance– it permits to machine 4 times more than the untreated one.
In order to understand the wear behavior of the cutting tools in micro-peeling, the average forces Fxc and Fyc (fig.3B) were measured during peeling and then the resulting specific cutting force Fc was calculated and shown on the figure 8. One can see the general correlation between the wear and the cutting forces. It may be noticed that the tool covered with the CrSiN film (i.e. the one with the smallest wear) shows smaller forces during machining.

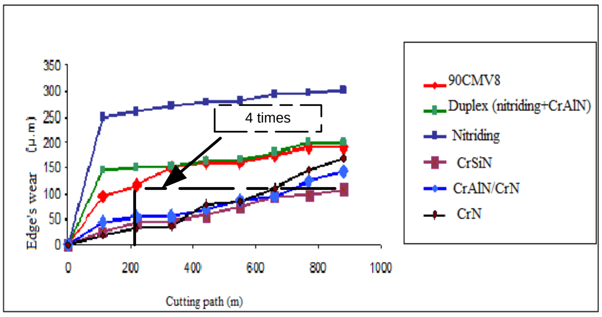


fig.7: Wear of the cutting edges versus the cutting path in micro-peeling of MDF.

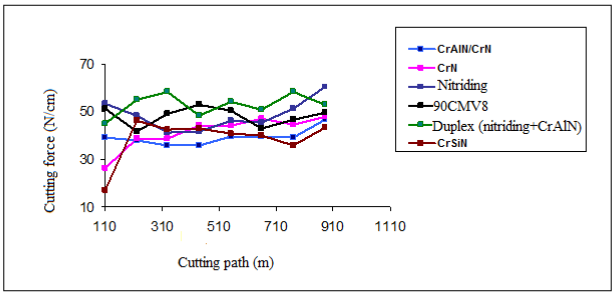


fig.8: Average specific cutting forces Fc during micro-peeling of beech for each knife

D. Microlathe shock tests of MDF

The tests of shocks were realized on the microlathe, while 4 stalks of beech (Φ 8mm) were introduced in the peripheral zone of the MDF disk (fig. 9). Their task was to simulate hard impacts during normal processing, similar to those caused by the knots in wood machining. Fig. 10 represents the shock test results seen on the microscopic images of the cutting edge before and after 20 shocks. Again the CrSiN-coated tool shows the lowest catastrophic wear of all the tools tested. One can also see that the nitrided tools have the biggest spalls of the cutting edge - this is because of its high superficial hardness

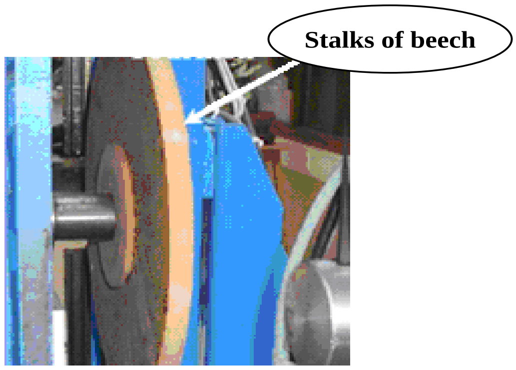
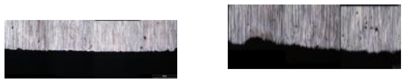


fig. 9: Shock testing setup

CrN-coated tool



Before shocks after shocks

CrSiN-coated tool

Before shocks fter shocks

Duplex treatment (nitriding+CrAlN) tool

Before shocks after shocks

CrAlN/CrN-cotated tool

Before shocks after shocks

Nitriding tool

Before shocks after shocks

Untreated tool

Before shocks after shocks

Fig. 12 : Microscopic images of the tools before and after shocks

E. Surface quality after machining

The quality of surface of wood or wood-based material is one of main purposes of machining, thus it is crucial to propose a durable tool capable of creating fine quality surfaces for as long as possible. The surface roughness is a criterion widely used for describing the quality of surfaces. , which depends on many cutting parameters including the tool wear. According to Aknouche and al. [11,12] the type of tool coating does not affect the quality of the surface but only the wear of the tool. However the results depicted in fig.12 indicate that the CrSiN-coated tool causes unequivocally lesser roughness as compared with other tools tested. One can also notice a visible correlation between the wear and the surface quality; when the wear increases the quality of surfaces decreases.

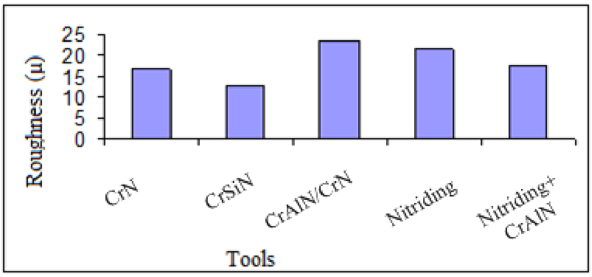


Fig.12: Surface roughness after 800 m of cutting

IV. Conclusion

The present study demonstrates the influence of different hard coatings on wood based material processing. It appears that the CrSiN coating deposed by pulverization magnetron gives better results than nitriding treatment, duplex treatments (nitriding+coating), multilayer's coatings (CrAlN/CrN) and CrN in all tests performed. The least reduction of the cutting edge has been observed for CrSiN coated knives, which resist scratching on MDF surfaces until 880m of cutting path. This may be due to a better adhesion of coating to the substrate and lower friction coefficient, which also decreases the cutting forces and make the cutting process more stable with regard to vibration, veneer thickness and quality of the surfaces.

Acknowledgment

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