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D. Morozow[1*], J. Narojczyk[1], M. Rucki[1], S. Lavrynenko[2]

[1] Kazimierz Pulaski University of Technology and Humanities in Radom, Faculty of Mechanical Engineering, ul. Krasickiego 54 B1, 26-600 Radom, Poland
[2]National Technical University, Kh.P.I, Information Technology & Systems KGM Dept. Kirpichova Street 2, Kharkov 61002, Ukraine
d.morozow@uthrad.pl

WEAR RESISTANCE OF THE CERMET CUTTING TOOLS AFTER ALUMINUM (Al^+) AND NITROGEN (N^+) ION IMPLANTATION

ABSTRACT

In the paper, the issue of the cermet cutting tools wear resistance was addressed. The tool inserts made out of cermet composites were exposed to the ion implantation with ions of nitrogen N^+ and with combination of nitrogen N^+ and aluminum Al^+ ions. In order to assess the impact of the ion implantation, the samples of stainless steel EZ6NCT25 were turned with the standard cutting tools and with the inserts after ion implantation. The results in general confirmed better wear resistance of the ion implanted inserts. In particular, they performed 20-40% smaller friction. After some time, when the destruction of the implanted surface layer took place, the friction coefficient rose up to the value typical for non-implanted inserts. For the implanted inserts, the wear index VB appeared to be lower, and even visual assessment revealed distinguishably smaller wear than in case of tools without ion implantation.

Keywords: *cermet, cutting tools, wear, wear resistance*

INTRODUCTION

Development of the sintering methods enabled to prepare nanostructured cutting tools out of different powders [1]. Nowadays, the cutting tools or the inserts are often made out of cermet, which is a composite material composed of ceramic (mainly TiC or TiN ceramics) ensuring high hardness and metallic materials, typically Ni, Co, Mo that form the binding phase. TiC provides hot hardness and wear resistance, oxidation resistance, chemical stability and improved notch resistance, while TiN provides fracture toughness and thermal shock resistance [2]. In general, cermets perform better on interrupted cuts, because their strength is higher than that of hot pressed ceramics [3]. The main advantages of cermet cutting tools are: better surface finish than that produced with carbides under the same conditions, high wear resistance, higher cutting speeds for the same tool life as carbides, or longer tool life when operated at the same cutting speed, and the costs per insert which is smaller for the cermets than for the plain carbides [4]. Cermets provide 20-100% longer life than coated carbides, and have excellent deformation resistance and high chemical stability, but relatively poor edge strength compared to sintered ceramics [2].

In order to improve the durability and wear resistance of the cermet cutting tools or inserts, small amounts of other ceramic materials are added, mainly Mo_2C, TaC, WC, TaN and VC. Compared to the typical sintered carbides based on WC-Co or WC-TiC-TaC-NbC-Co, the cermets has got lower density between 6 and 7.5 g/cm^3, which is a result of the presence of titanium carbides and nitrides [5].

The ion implantation proved to be the process, which improves the surface layer properties. It was decades ago, when the significant reduction in friction and wear of the iron and titanium systems was achieved due to the hard layer formed during the ion implantation process [6]. So it was reasonable to expect the improvement the wear resistance of the cermets as well, and the investigations confirmed those expectations.

The layers with diverse physical and mechanical properties can be created using PVD methods, with proper the selection of the process, its parameters and components according to the desired characteristics [7, 8]. Ability to obtain specific microstructure and hardness was demonstrated [9], and possibility of controlling the residual stress in the subsurface layers of the coating was also reported [10]. Ion implantation techniques proved to be able to obtain similar modifications of the structure, e.g. to facilitate the process of layer deposition using IBAD, and thus to induce changes in tribological properties [11], hardness or surface layer tensions [12, 13].

After application of these techniques, reduced wear of the cutting tools was noticed. Some papers reported results of the study of the ion implantation effects on surface contour, microhardness, micro-, and submicrostructures, as well as chemical composition of surface layers of cermet hard alloy tools and high-speed steel tools. The authors [14] performed the wear resistance tests for the implanted tools and revealed that the effect depends on the type of machined material and on the machining process conditions. Other researchers [15] focused on the control of friction coefficient.

However, despite of the importance of tool life and wear resistance [16] only few studies can be found that assess the influence of ion implantation on the lifetime of carbide inserts at higher temperatures under real working conditions [17, 18].

INVESTIGATION METHODS

In the experimental research, the multi-edge cutting tool inserts type CNMG 120404-MF (made by Sandvik Coromant) were used. They were made out of the uncovered cermet CT5015 based on TiCN, designed for the continuous turning, of very high wear resistance. The rake face of the cermet inserts underwent the ion implantation procedure with the nitrogen ions or with nitrogen and aluminum ions. The procedure of ion implantation was carried out in the National Center of the Nuclear Research (Otwock/Świerk, Poland) with the ion implantation device for metals TITAN equipped with spark source of metal couples MEVVA type (Metal Vapour Vacuum Arc). The parameters of the implantation are presented in the Table 1.

Table 1. *Parameters of the cermet inserts ion implantation*

No.	Material	Ion type	Doze	Energy
1	CNMG 120404-MF cermet CT5015	N^+	2×10^{17} ion/cm^2	65 keV
2	CNMG 120404-MF cermet CT5015	$Al^+ + N^+$	1×10^{17} ion/cm^2 1×10^{17} ion/cm^2	65 keV

The microhardness of the surface layer covered by ion implantation was measured with the Vickers type device, model 401 MVD made by Wilson Wolpert.

Next, the inserts were fixed in the holder DCLNL 2020K 12 type, shown in the Fig. 1. With those inserts, the stainless steel samples EZ6NCT25 were machined. The geometry of the cutting edge during the machining was as follows:

- Tool clearance angle $\alpha = 6°$,
- Tool rake angle (negative) $\gamma = -6°$,
- Tool cutting edge angle $\kappa_r = 95°$,
- Corner radius $r_\varepsilon = 0.4$ mm.

Technological parameters of the machining were as follows:

Depth of cut $a_p = 0,5$ mm, Cutting speed (velocity) $v_1 = 50$ m/min and $v_2 = 70$ m/min, feed rate $f = 0.15$ mm/rev.

All the machining experiments were performed at the same cooling conditions with 5% emulsion BlastCut2000. The turning center DMG NEF 400V was used. In order to assess the components of the cutting forces (tangential component F_c, feeding component F_f, and resistance component F_p), the tensometric force measurement device CL 16 type was installed (Fig. 2). The sampling time was 0.1 s.

Fig. 1. The holder DCLNL 2020K 12 and the set of the inserts CNMG 120404-MF (material CT5015)

Fig. 2. The cutting forces tensometric measurement device CL 16 type

The machined samples were made out of austenite heat resistant steel EZ6NCT25 (according to the DIN standard: X5NiCrTi2615). Its chemical composition is presented in the Table 2. The samples were of diameter 85 mm and length l = 72 mm. The hardness of those samples was 35 HRC.

Table 2. *The chemical composition of the steel EZ6NCT25 (X5NiCrTi2615), wt. %*

C	Ni	Cr	Ti	Mn	V	Si	Fe
max. 0.8	24 - 27	13.5 - 16	1.9 – 2.35	1.0 – 2.0	0.1 – 0.5	max. 1.0	rest

RESULTS AND DISCUSSION

The results of microhardness measurement of the inserts before ion implantation and after it reveal that the nitrogen ion implantation has substantial impact on the characteristics of the rake face. The Table 3 presents the obtained measurement results. It is seen that the inserts implanted with nitrogen ions only, have got increased microhardness of 249 μHV 0.2, while the ones implanted with nitrogen and aluminum ions reveal negligible increase of microhardness (of 54 μHV 0.2).

Table 3. *The results of microhardness measurement of CNMG inserts*

No.	Material	Hardness μHV 0.2
1	CNMG 120404-MF (CT5015) non-implanted	1914.5 ±158
2	CNMG 120404-MF (CT5015) implanted with N^+	2163.0 ±175
3	CNMG 120404-MF (CT5015) implanted with N^+ and Al^+	1968.0 ±159

Even the visual inspection enables to notice better wear resistance of the ion implanted inserts. Fig. 3 presents the photos of the inserts CNMG 12040-MF seen from the rake surface side after the work at speed v_1 = 50 m/min during t = 300 s.

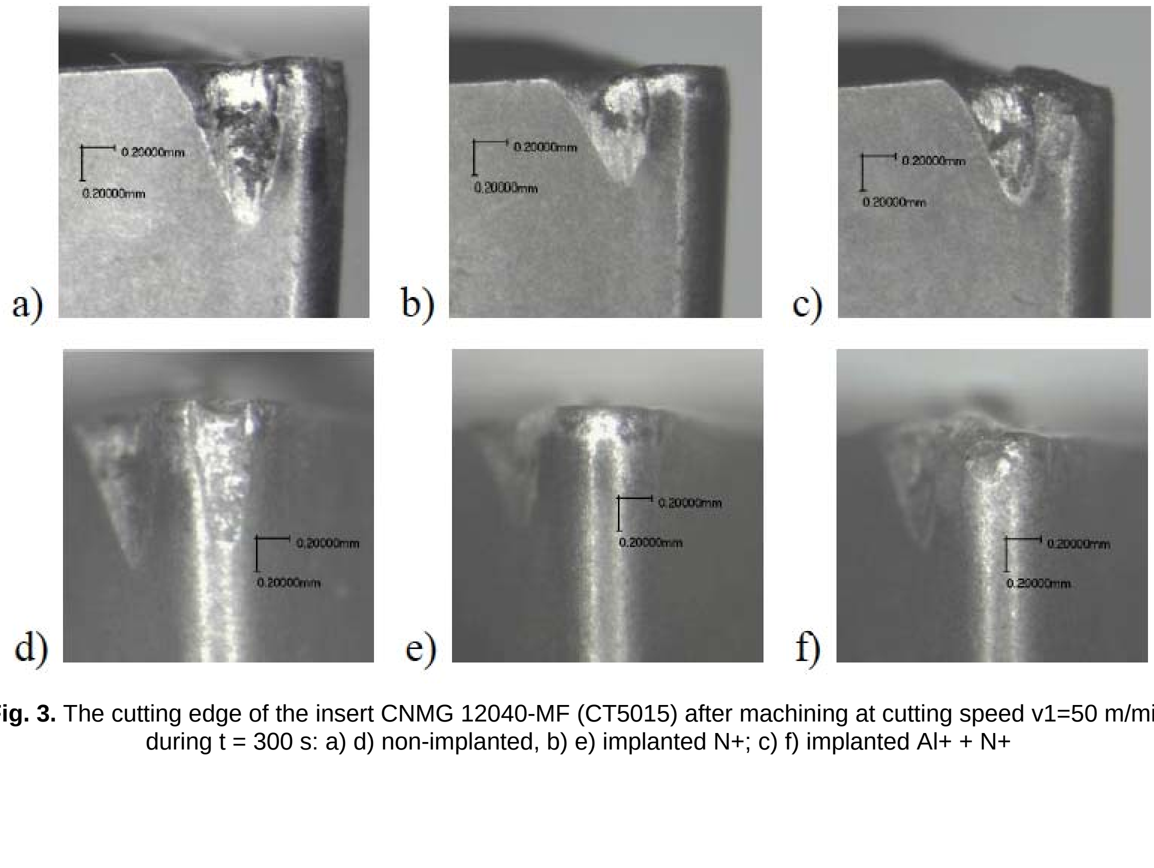
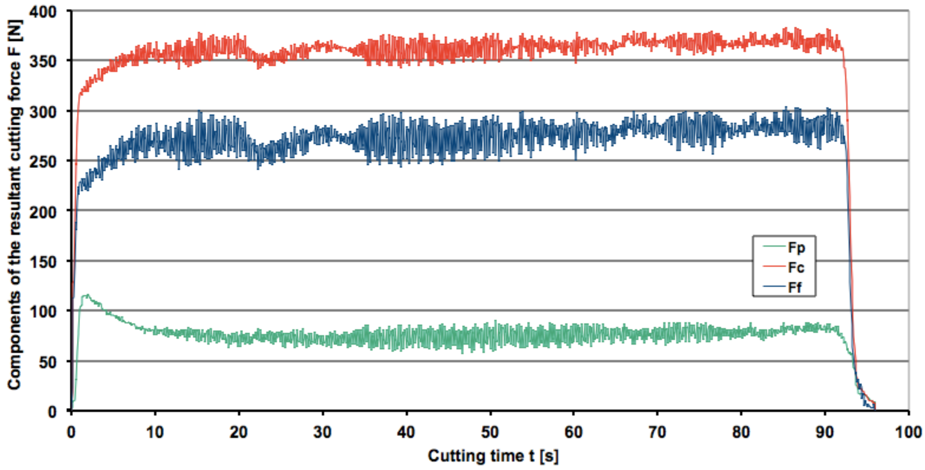


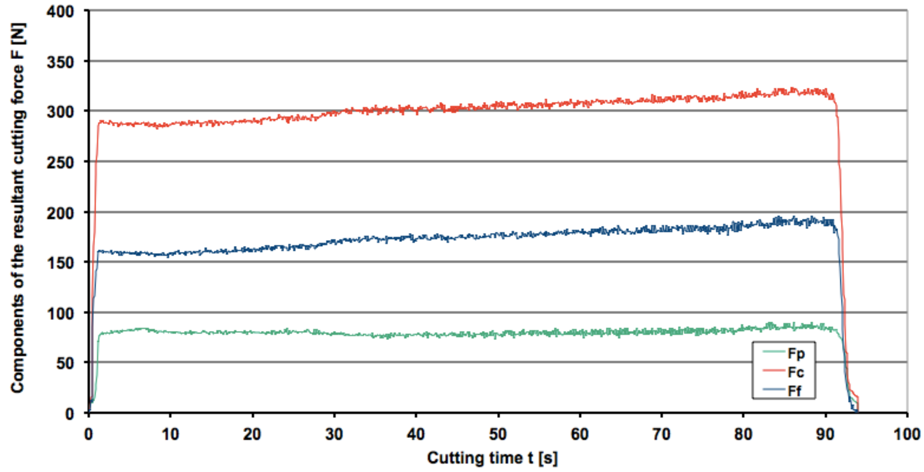
Fig. 3. The cutting edge of the insert CNMG 12040-MF (CT5015) after machining at cutting speed v1=50 m/min during t = 300 s: a) d) non-implanted, b) e) implanted N+; c) f) implanted Al+ + N+

The examples of registered cutting forces are presented in the Figure 4 for the insert CNMG without ion implantation, with ions N^+ only, and with ions Al^+ + N^+. The parameters of the machining were: v_1=50 m/min; t = 90 s. Other experiments were made also at the cutting speed v_2=70 m/min with different time intervals: 100 s and 300 s.

a)



b)



c)

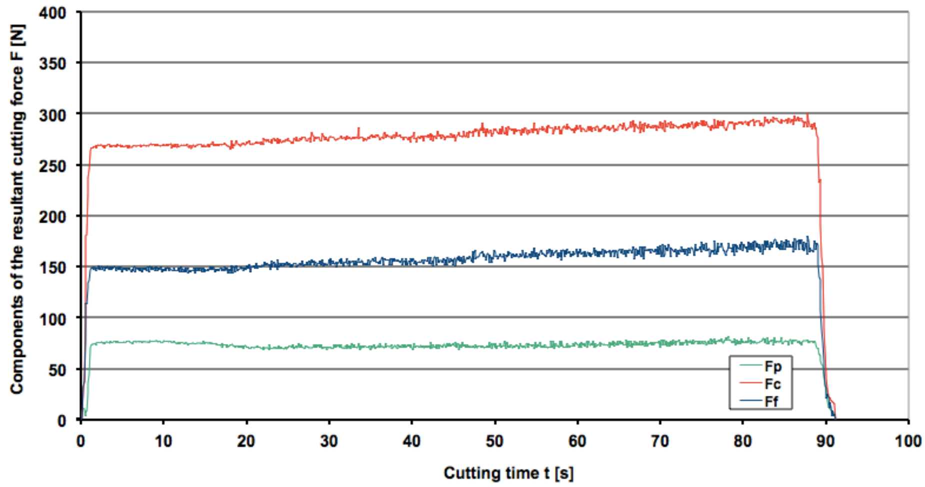


Fig. 4. Registered cutting forces for the insert CNMG at v1=50 m/min; t = 90 s: a) without ion implantation, b) with ions N+ only, and c) with ions Al+ + N+

The registered values of cutting force components reveal significant differentiation of the appearing resistance. Especially it is seen in case of the tangential component F_c and feeding component F_f in the initial phase of the machining with the implanted inserts compared to non-implanted ones. The component F_c decreased for 15% and 20%, while the component F_f for 35% and 40%.

The measurement of the rake surface wear proved that the implanted inserts are substantially more wear-resistant. The parameters VB_c and VB_n determined according to the standard PN-ISO 3685:1996, are significantly smaller for the inserts with ion implanted surfaces. The example of the VB_c and VB_n graphs obtained for the cutting speed v_1=50 m/min are presented in the Fig. 5.

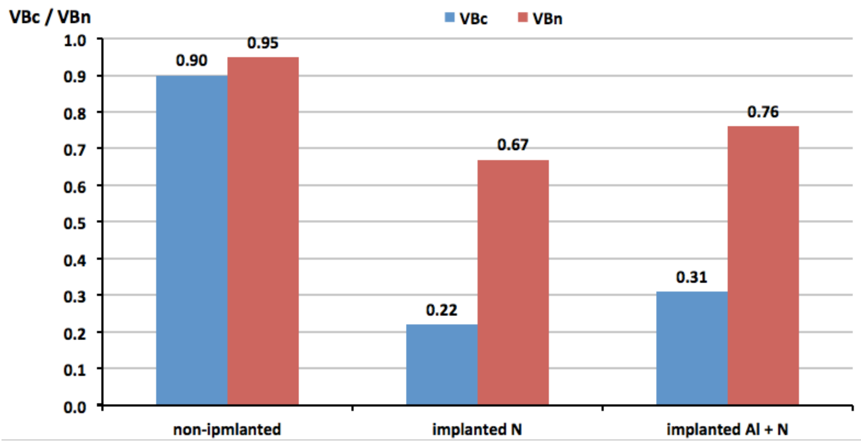


Fig. 5. The parameters VBc and VBn obtained for the cutting speed v1=50 m/min

The obtained results are difficult to compare with other reports, since no paper presents exactly the same experiments. One of the most recent reports concerning impact of MEVVA implantation method on wear resistance [19] does not include Al^+ ions. It does not analyze the impact of ion implantation on the real cutting conditions. On the other hand, there are papers reporting analysis of cermet cutting tools performance, e.g. [20], but they do not consider ion implantation. The presented above original results provide new perspective on the N^+ and Al^+ ion implantation impact on the performance of cermet cutting tools. The findings are important because higher cutting speed contributes significantly to an increase in productivity. Additionally, when the lifetime of cutting tools is longer, downtimes caused by tool changes as well as the amount of cooling lubricants can both be reduced [21].

CONCLUSIONS

The investigations were aimed to assess the wear resistance of cermet cutting tools after ion implantation. To achieve the goal, the inserts CNMG underwent the ion implantation using MEVVA method, with nitrogen ions only and with both aluminum and nitrogen ions. Then the inserts were tested during cutting process, as well as the non-implanted ones.

The research proved the substantial increase of microhardness after the N^+ implantation, while the implantation of N^+ and Al^+ did not cause such an effect. In all cases, however, the parameters VB_c and VB_n after implantation became smaller indicating the increased wear-resistance. The noteworthy effect was the decrease of the friction after ion implantation.

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