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Raziskave difuzije skozi stik PVD prekrito orodje iz kermeta/obdelovanec

An Investigation of the Diffusion Across a PVD-Coated Cerment Tool/Workpiece Interface

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Upoštevajoč omejitve pri izboljšanju mehanskih lastnosti rezalnih orodij, obstajajo nadaljnje možnosti za izboljšanje učinkovitosti orodja le na podlagi zmanjšanja termokemijske obrabe, ki je posledica poteka difuzije. To je mogoče doseči z izbiro ustrezne kombinacije med osnovnim materialom orodja in prevleko PVD (fizikalno nanašanje v vakuumu), ki kar se da upočasni potek difuzijske obrabe, ali vsaj ne poslabša mehanskih lastnosti podlage – osnovnega materiala orodja.

V tem prispevku je raziskovana difuzija skozi stik PVD prekrito orodje iz cermeta na obdelovanec. Za študij termo-kemijske obrabe cermetov na temelju Ti(C,N), prekritih s prevleko TiN (PVD) ali TiZrN (PVD) kot difuzijsko pregrado, je uporabljena metoda difuzijskih členov.

(Ključne besede: prevleke PVD, cermeti, procesi difuzijski, procesi termokemični, obraba)

Taking into account the limitations that exist when it comes to improving the mechanical properties of cutting tools, further possibilities to improve tool performance might be found in reducing the thermochemical wear, which is a result of a diffusion process. This reduction is possible if we choose a favorable combination of substrate and PVD (Physical Vapour Deposition) coating in which the process of diffusion wear is slowed down as much as possible or is not detrimental to the mechanical properties of the substrate, which is the basic material of the tool.

In this work the diffusion across a coated cermet tool/workpiece interface was studied. Recently, the diffusion-couple method was used to study the thermochemical wear of Ti(C,N)-based cermets coated with TiN (PVD) and TiZrN (PVD) coatings as a diffusion barrier.

(Keywords: PVD coatings, cermets, diffusion processes, thermochemical processes, wear)

0 UVOD

Nove usmeritve pri razvoju karbidnih trdin vključujejo tudi kermete kot rezalne materiale, ki so bili predmet številnih razprav v preteklih letih, tako v objavah kakor tudi na konferencah ([1] do [4]). Kljub veliki odpornosti kermetov proti obrabi in majhni nagnjenosti k adheziji, prevleke prav tako poudarijo prednosti teh rezalnih materialov.

Večina objav na področju obrabe kermetov ([5] do [8]) se ukvarja s termomehansko obrabo medtem ko so termokemijski procesi na dotiku med orodjem in obdelovancem manj temeljito raziskani. Še posebej primanjkuje podatkov o mehanizmih obrabe prekritih orodij iz kermeta.

V vsakem tribološkem dotiku pri odrezovanju materialov pomeni prevleka na orodju zaščitno plast proti zelo visokim temperaturam in dotikalnim pritiskom. Temperature rezanja nad 650 °C so značilne

0 INTRODUCTION

New trends in hard-metal development include the use of cermets as cutting materials. These materials have been the subject of many discussions in recent years, in publications and at conferences ([1] to [4]). Despite the high wear resistance of cermets and their low adhesive tendency, coatings can offer certain advantages to these cutting materials.

The majority of the publications in the field of cermet wear ([5] to [8]) deal with thermomechanical wear, while the thermochemical processes at the contact between the tool and the workpiece have been less thoroughly researched. In particualr, there is not enough data about the wear mechanisms of coated cermet tools.

In every tribocontact in the cutting of materials the coating on the tool is a protective layer against the very high temperatures and contact pressures. Machining with HSS tools at temperatures above pri obdelavi z orodji iz HSS, medtem ko so temperature nad 1000 °C značilne za obdelavo pri velikih hitrostih in obdelavo v trdo jekel in zlitin z orodji iz karbidnih trdin ali kermetov, prekritih s prevlekami CVD oz. PVD. Pri teh visokih dotikalnih temperaturah difuzijo atomov materiala orodja v odrezek spremlja občuten padec mikrotrdote, korozijske odpornosti, odpornosti proti obrabi ter trdnosti orodja.

Obsežni testi so bili opravljeni z namenom, da bi določili zmožnosti in omejitve pri uporabi kermetov kot rezalnih materialov ([9] in [10]). Rezultat procesa difuzije elementov orodja in obdelovanca skozi vmesnik je sprememba sestave mejne plasti orodja, ki povečuje možnost mehanske poškodbe rezalnega robu. V primeru odrezovanja s prekritim orodjem opazimo ta pojav po daljšem času uporabe v primerjavi z neprekritim orodjem.

1 EKSPERIMENTALNO DELO

1.1 Priprava difuzijskih členov

Vzorci za analizo pojavov na dotiku orodje/obdelovanec so bili sestavljeni iz dela rezalne ploščice iz kermeta, prekrite s prevleko PVD (debeline 3 μm), ploščice iz železa Armco in tehnično čistega prahu železa (sl. 1) [10].

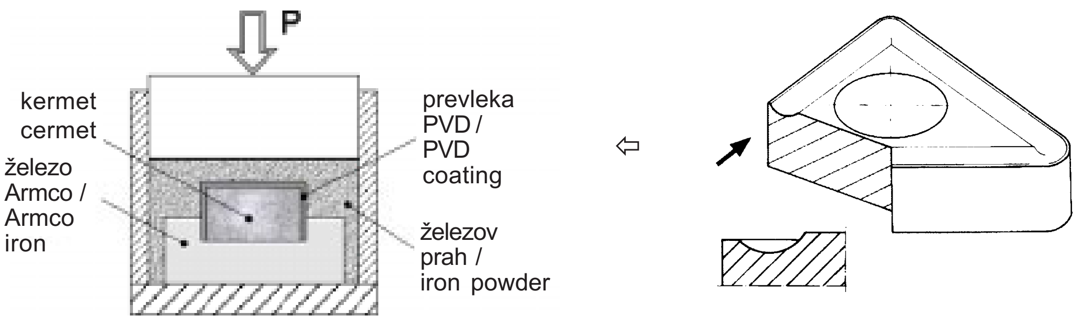
650°C is not possible, and temperatures above 1000°C are common in the high-speed and heavy-duty machining of steels and alloys with CVD-or PVD-coated carbides or cermets. At these high contact temperatures the chemical dissolution of the tool material into the chip on an atomic scale is accompanied by a rapid decrease in the microhardness, corrosion resistance, wear resistance and the strength of the tool.

Extensive tests were carried out in order to determine the performance capabilities and operating limits of cermet cutting materials ([9] and [10]). The result of the diffusion of an element from the tool and the workpiece through the interface is a change in the composition of the boundary layers of the tool, which increases the possibility of mechanical damage to the cutting edge. In the case of cutting with coated tools these phenomena occur after a longer time of service in comparison to uncoated ones.

1 EXPERIMENTAL WORK

1.1 Preparation of Diffusion Couples

The samples for the analysis of the phenomena in the tool/workpiece contact were taken from a part of a PVD-coated cermet cutting insert (the thickness of the coating was 3 μm), an Armco-iron insert and technically pure iron powder, Figure 1 [10].



Sl. 1. *Struktura difuzijskega člena*
Fig. 1. *Composition of the diffusion couple*

Dufuzijski členi so bili narejeni tako, da so v neposrednem dotiku, povzročenem s silo, trdna ploščica iz železa Armco ali železov prah s kermetom, prekritim s TiN (PVD) ali prevleko TiZrN (PVD) oz. z neprekritim kermetom.

Razlog za takšno obliko sklapljanja vzorcev je bil v tem, da so deli kermeta, izrezani iz realnih ploščic, zaradi svoje oblike na cepilni ploskvi neprimerni za pripravo standardnih difuzijskih parov. Kljub temu je bil v tem primeru tesen dotik med vsemi elementi difuzijskega člena (premera 15 mm) dosežen z uporabo pritisne sile 250 kN. Zaradi te obremenitve se je del ploščice iz kermeta zaril v zelo mehko ploščico iz železa Armco, medtem ko se je železov prah tesno oprijel

Diffusion couples were made by bringing into contact a solid plate of Armco iron or iron powder and the use of force to make an intimate and strong contact between the partners with TiN (PVD)-coated cermet, TiZrN (PVD)-coated cermet, and uncoated cermet.

The reason for this kind of coupling of the samples was in that some parts from the cermet, cut out from real insert shapes, were unsuitable for the preparation of normal diffusion couples. Nevertheless, in this way a tight contact between all the elements was obtained since in the making of the diffusion couples (diameter 15 mm) a pressure of 250 kN was applied. Under this load a part of the cermet was pressed into the very soft Armco-iron insert while the iron powder was tightly compacted. This made profilirane površine kermeta, kakor se zahteva za difuzijske teste. Višina stisnjenih vzorcev je bila v mejah od 10 do 12 mm.

1.2 Opis pojavov

Po končani pripravi difuzijskih členov je bil opravljen postopek difuzijskega žarjenja v cevni peči, v atmosferi $H_{2,}$ pri temperaturi 1000 ± 3 °C. To je privedlo do sintranja poprej stisnjenega železovega prahu. Čas žarjenja je bil 1 ura za polovico vzorcev. Da bi ugotovili učinek časa segrevanja na debelino reakcijske plasti, je bil čas žarjenja v cevni peči za drugo polovico vzorcev podaljšan na 24 ur.

Železov prah vsebuje kisik v obliki oksidov na površini prahastih delcev. V danih razmerah (1000 °C, H_2) se železov oksid razgradi in nastane vodna para. Železov oksid oz. vodna para sta bila glavna (edina) vira kisika, potrebnega za oksidacijo prevlek TiN (PVD) in TiZrN (PVD) oz. kermetov v raziskovanih difuzijskih členih. Izmed vseh elementov, vsebovanih v "difuzijskem paru" kermet/železo: Ti, W, Mo, Ni, Co in Fe ima titan največjo privlačnost do kisika, s katerim tvori vrsto različnih oksidov (TiO, Ti_2O_3, Ti_3O_5, Ti_4O_7 in TiO_2). Prosta energija nastanka titanovega ali cirkonijevega nitrida je veliko bolj negativna kakor proste energije nastanka vseh preostalih spojin (npr. WC, MoC, TiC, TiN or ZrN) [11]. Zaradi tega v navzočnosti kisika te spojine oksidirajo, še posebej Ti (pa tudi Zr). Med naštetimi elementi ima najmanjšo privlačnost do kisika Ni. Zaradi tega je kermet material, v katerem se pojavlja t.i. selektivna oksidacija.

Med omenjenimi oksidi titana sodi TiO_2 v skupino n-polprevodnikov (s presežkom kovinskih ionov), medtem ko sta TiO in Ti_2O_3 amfoterna prevodnika (kovinska prevodnika). TiO_2 raztaplja WO_3 tako kakor NiO in kakor kažejo meritve, izmed preostalih elementov tudi železove okside. Ko je nastala plast titanovega oksida se proces oksidacije upočasni, stopnja oksidacije se sedaj vodi s stopnjo difuzije elementov skozi titanov oksid. Ker je koncentracija titana v plasti TiN in/ali v kermetu veliko večja od koncentracije preostalih elementov ter je njegova privlačnost do kisika znatno večja v primerjavi s preostalimi (z izjemo Zr), v glavnem oksidira titan. Nikel, kot veliko bolj plemenita kovina v tej kombinaciji, se nabira in bogati na strani kermeta, kar se izkaže v povečanju koncentracije niklja in opazi kot "svetla" (bela) ali plast "C" – mejna plast "prizadetega" rezalnega materiala (sl. 2).

2 ANALIZA DIFUZIJSKEGA ČLENA

Kakor je razvidno s slik 2 (a) in (b) pri danih pogojih se je oblikovala široko vplivana difuzijska

the contact with the profiled cermet surface very tight, as required for the diffusion tests. The height of the pressed pieces was between 10 and 12 mm.

1.2 Description of the phenomena

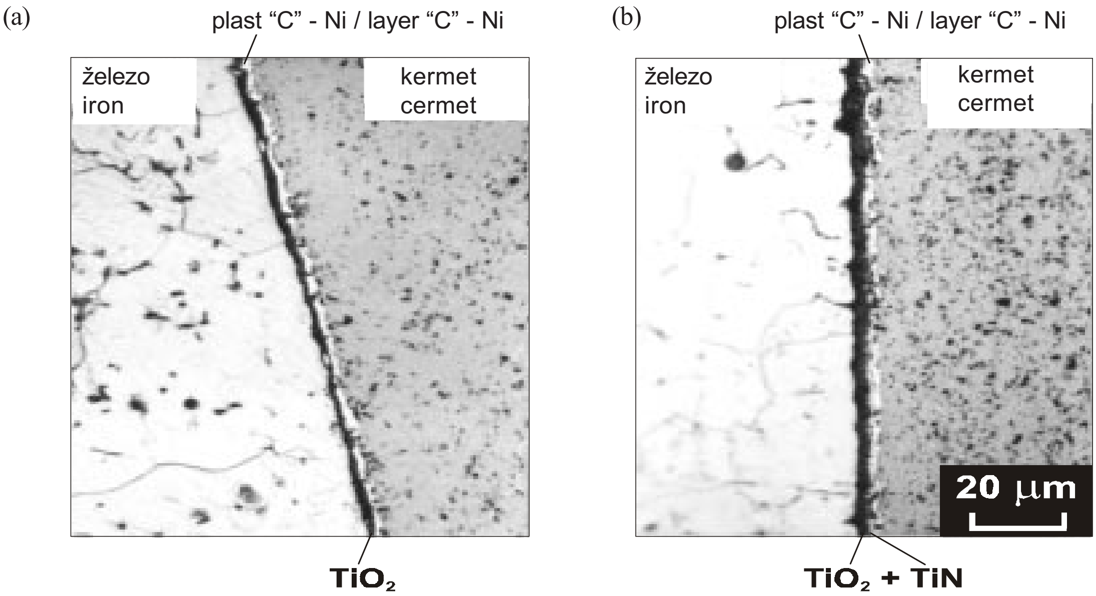
After preparing the diffusion couples the process of diffusion annealing was carried out in a tube furnace in a H_2 atmosphere at a temperature of 1000 ± 3 °C. This led to sintering of the previously compacted iron powder. The annealing time was 1 hour for half of samples. In order to establish the effects of heating time on the width of the reaction layer, for other samples the time of their heating in the tube furnace was prolonged to 24 hours.

Iron powder contains oxygen in the form of oxides on the surface of the powder particles. Under certain conditions (1000 °C, H_2) the iron oxides reduce and water vapor is formed. Iron oxides or water vapor were the main source of oxygen for the oxidation of TiN (PVD) and TiZrN (PVD) coatings or the cermets in the studied diffusion couples. Among all the elements contained in the cermet/iron diffusion couple Ti, W, Mo, Ni, Co and Fe — it is the titanium that has the highest affinity for oxygen, forming a series of different oxides — TiO, Ti_2O_3, Ti_3O_5, Ti_4O_7 and TiO_2. The free energy of formation of titanium and zirconium oxides is much more negative than the free energy of formation of all the compounds present in the diffusion couples, for example WC, MoC, TiC, TiN or ZrN [11]. Therefore, in the presence of oxygen these compounds oxidize, especially the Ti and the Zr. Among the elements present the lowest affinity to oxygen is found with the nickel. Thus, cermet is a material in which so-called selective oxidation takes place.

TiO_2 belongs to the group of n-type semiconductors (with a surplus of metallic ions) whereas TiO and Ti_2O_3 are amphoteric conductors (metallic conductors). TiO_2 dissolves WO_3 as well as NiO and, as measurements show, from among the other elements, also iron oxides. Once a layer of titanium oxide has been formed, the process of oxidation slows down as the rate of oxidation is now controlled by the rate of diffusion of elements through the titanium oxide. Since the concentration of titanium in the TiN and/or cermet layer is much higher than the concentration of the other elements and its affinity to oxygen is considerably higher than the affinity of the others (except Zr), it is mainly the titanium that oxidizes. Nickel, as a much more precious metal in this combination, accumulates and gets richer on the cermet side, which can be seen in the increase of nickel concentration and the occurrence of "bright" (white) or layer "C" – boundary layer of the "affected" tool material, Figure 2.

2 ANALYSIS OF THE DIFFUSION COUPLE

As is evident from Figure 2 (a) and (b), under the given conditions a wide diffusion-affected zone



Sl. 2. *Optični posnetek prereza difuzijskih členov: (a) neprekrit cermet/železo Armco (temna plast - titanov oksid, svetla plast - nikelj) in (b) cermet, prekrit s prevleko JOSTiN^R/železo Armco (temna plast - titanov oksid + TiN, svetla plast - nikelj).*

Fig. 2. *Optical micrograph of the diffusion couples of: (a) uncoated cermet/Armco iron (dark layer - titanium oxide, bright layer - nickel) and (b) JOSTiN^R coated cermet/Armco iron (dark layer - titanium oxide + TiN, bright layer - nickel).*

cona v kermetu, na dotiku med neprekritim ali prekritim kermetom/železom. Z EMPA (elektronska analiza na mikro vzorcih) črtno analizo je bilo ugotovljeno, da je zaradi difuzije Ti nastala mejna plast bogata predvsem z Ni.

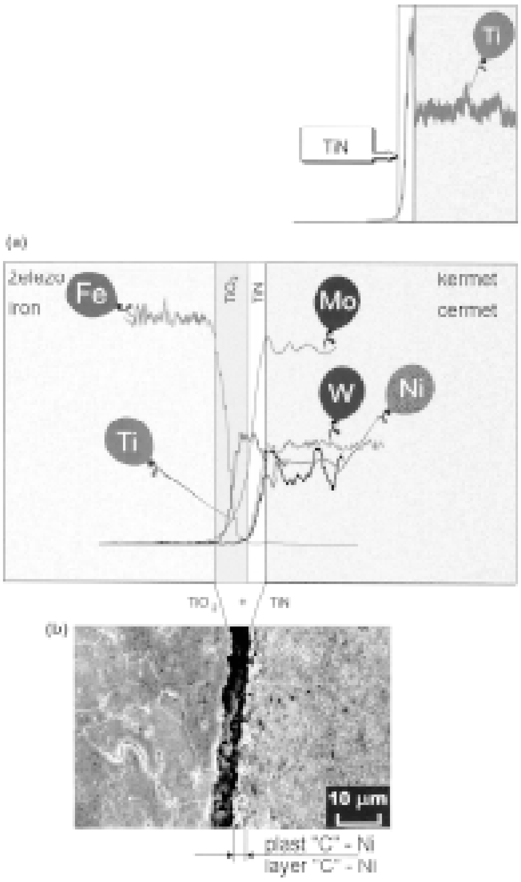
Najprej je bila narejena analiza difuzijskega člena, sestavljenega iz železa Armco in prekritega kermeta s prevleko TiN (PVD). Slika 3 prikazuje SEM (vrstična elektronska mikroskopija) mikroposnetek prečnega prereza difuzijskega člena in ustrezne rezultate polkvantitativne analize EMPA. Po enournem žarjenju na 1000 °C plast TiN oksidira in nastane oksid, najverjetneje TiO_2, medtem se en del oksida nastane tudi na račun oksidacije titana iz kermeta. Zaradi oksidacije titana se kemijska sestava kermeta vzdolž meje s titanovim oksidom spremeni. Prav za titanovim oksidom je bilo opaženo močno zmanjšanje koncentracije titana v kermetu, kar kaže na to, da je bil titan porabljen v oksidacijskem postopku in pri rasti oksidacijskega pasu. Profil koncentracije opozarja na določeno stopnjo spojitve nekaterih drugih elementov v titanovem oksidu, še posebej volframa in molibdena. Hkrati se je zgodila delna prerazporeditev niklja v tem delu kermeta.

V difuzijskem členu, ki je sestavljen iz železa Armco in prekritega kermeta s prevleko TiZrN (PVD), po enournem žarjenju na 1000 °C plast PVD popolnoma oksidira. Slika 4 kaže mikroposnetek SEM prečnega prereza skozi omenjeni difuzijski člen ter rezultate polkvantitativne analize EMPA. Vzdolž oksida ima kermet podobno mikrostrukturo kakor v prejšnjem primeru (sl. 3). Povečan je znesek faze,

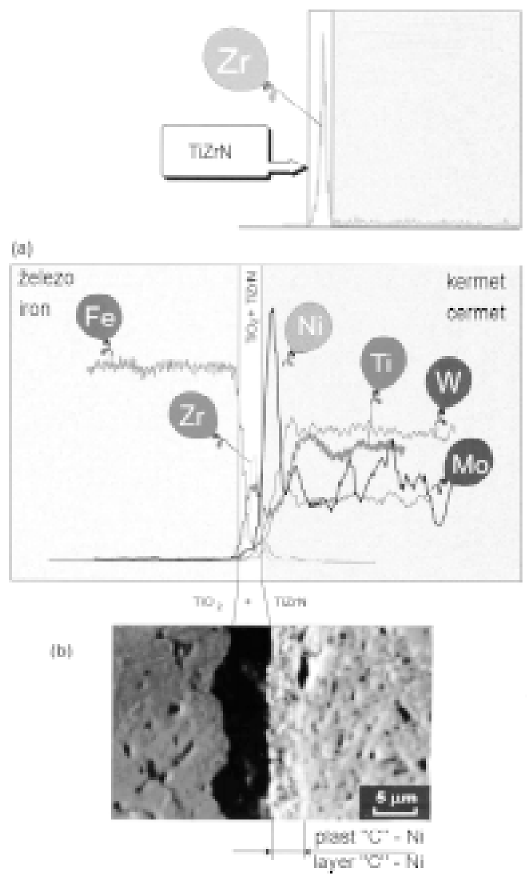
was created in the cermet in the contact between the uncoated or coated cermet/iron. With the EMPA (Electronic Micro Probe Analysis) line analysis it was found that due to diffusion of Ti the created boundary layer is rich in Ni.

First, a thorough analysis of the diffusion couple consisting of Armco iron and TiN (PVD)-coated cermet was made. Figure 3 shows a SEM (Scanning Electron Microscopy) micrograph of the cross-section through the diffusion couple and the corresponding results of the semi-quantitative EMPA analysis. After a one-hour annealing at 1000 °C the TiN layer oxidized to form an oxide, most probably TiO_2, while one part of the oxide was formed as a result of the oxidation of titanium from the cermet. Due to the oxidation of titanium the chemical composition of the cermet along the boundary with the titanium oxide changes. Immediately behind the titanium oxide a very much reduced concentration of titanium in the cermet occured, which shows that the titanium was consumed in the oxidation process and the growth of the oxidation belt. The concentration profiles point to a certain degree of fusibility of some of the other elements in the titanium oxide, especially tungsten and molybdenum. At the same time a partial redistribution of the nickel takes place in this part of the cermet.

In the diffusion couple, consisting of Armco iron and TiZrN (PVD)-coated cermet, after a one-hour annealing at 1000°C the PVD layer totally oxidized. Figure 4 shows an SEM micrograph of the cross-section through the mentioned diffusion couple and the results of the semi-quantitative EMPA analysis. Along the oxide the cermet has a similar microstructure as in the previous case (Fig. 3), however, there is an increase in



Sl. 3. *Polkvantitativne analiza EMPA difuzijskega člena kermet, prekrit s TiN/železom Armco (a) in ustrezen posnetek SEM (b); ($t_ž$ = 1^h, 1000 ^{o}C).*
Fig. 3. *Semi-quantitative EMPA analysis of the TiN-coated cermet/Armco iron diffusion couple (a) and corresponding SEM micrograph (b); (t_{an} = 1^h, 1000 ^{o}C).*



Sl. 4. *Polkvantitativna analiza EMPA difuzijskega spoja kermet, prekrit s TiZrN/železom Armco (a) in ustrezen posnetek SEM (b); ($t_ž$ = 1^h, 1000 ^{o}C).*
Fig. 4. *Semi-quantitative EMPA analysis of the TiZrN-coated cermet/Armco iron diffusion couple (a) and corresponding SEM micrograph (b); (t_{an} = 1^h, 1000 ^{o}C).*

bogate z nikljem ter faze, bogate z volframom in molibdenom. Posredno to tudi podpira ugotovitev o pojavu selektivne oksidacije kermeta pod oksidom in tako to območje postaja revno s titanom ([12] in [13]).

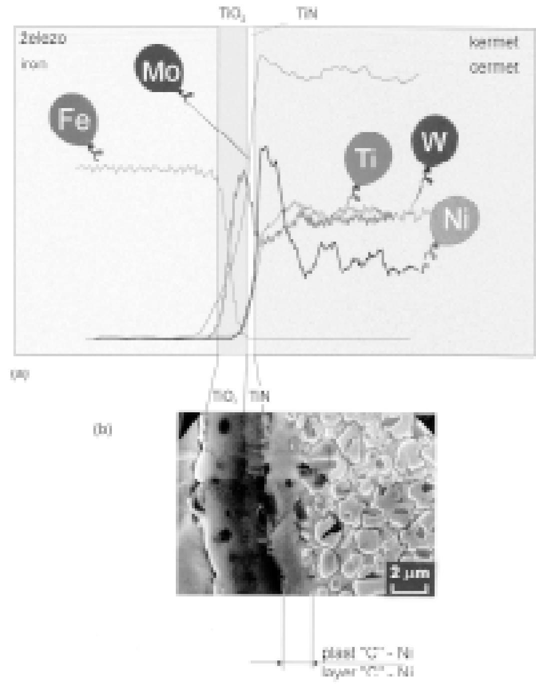
Da bi ugotovili vpliv časa segrevanja na debelino reakcijske plasti, je bil, za nekaj vzorcev difuzijskih členov, čas segrevanja v cevni peči podaljšan za 24 ur. Pričakovano je bilo, da se bo debelina reakcijske plasti bistveno povečala. Debelina plasti titanovega oksida je približno enaka, ne glede na to, ali je žarjenje pri 1000 ^{o}C trajalo 1 uro ali 24 ur, kar podpira zamisel o preventivnem delovanju atmosfere na mejno površino. Rezultati polkvantitativne analize EMPA tega difuzijskega člena ter ustrezni mikroposnetek SEM so prikazani na sliki 5.

Difuzijski člen železo Armco/neprekriti kermet je bil žarjen na enak način, pri 1000 ^{o}C 1 uro. V tem primeru (sl. 2a) se na dotiku prične selektivna oksidacija kermeta takoj. Primarno oksidira titan, medtem ko je v titanovem oksidu vzdolž meje z

the portion of the phase rich in nickel and the phase rich in tungsten and molybdenum. Indirectly, this too is a supporting statement for the selective oxidation of the cermet under the oxide taking place and this part becoming poor in titanium ([12] and [13]).

In order to establish the effects of heating time on the width of the reaction layer the heating time in the tube furnace was prolonged to 24 hours for some of the diffusion couple samples. It was expected that the thickness of the reaction layer would increase significantly. The thickness of the titanium oxide layer is approximately the same, irrespective of whether the annealing at 1000 ^{o}C lasted 1 hour or 24 hours, which supports the idea of prevented access of the atmosphere to the boundary surfaces. The results of the semi-quantitative EMPA analysis of this diffusion couple and the corresponding SEM micrograph are presented in Figure 5.

The Armco iron/uncoated cermet diffusion couple was annealed in the same way at 1000 ^{o}C for 1 hour. In this case (Fig. 2a) selective oxidation of the cermet in the contact started happening right away. Primarily it was the titanium that oxidized, while in the



Sl. 5. *Polkvantitativna analiza EMPA difuzijskega spoja kermet, prekrit s TiN/železom Armco (a) in ustrezen SEM posnetek (b); ($t_ž$ = 24^h, 1000 ^{o}C).*
Fig. 5. *Semiquantitative EMPA analysis of the TiN-coated cermet/Armco iron diffusion couple (a) and corresponding SEM micrograph (b); (t_{an} = 24^h, 1000 ^{o}C).*

železom še nekaj raztopljenega železa in na meji s kermetom nekaj raztopljenega W in Mo. Vzdolž oksida se drugi elementi v kermetu bogatijo v fazo, bogato z nikljem in fazo, bogato z volframom in molibdenom.

Rezultati raziskav potrjujejo, da je *plast "C"* (mejna plast prizadetega rezalnega materiala) v vseh primerih skrajno bogata z Ni, hkrati pa v tem področju ni opaznega zmanjšanja deleža Ti, ki prodira skozi prevleko, oksidira in se nalaga na prevleko na strani železa Armco.

Oksidacija in pas titanovega oksida preprečujeta normalno napredovanje difuzije med čistimi partnerji: kermet, prevleka in železo. Nastanek oksidacijske plasti je verjetno bolj realen pojav pri odrezovanju kakor verjetnost, da bo ostala površina rezila neoksidirana pri tako visoki temperaturi (800 to 1000 ^{o}C). To je razlog, da difuzijski poskusi, opravljeni na takšen način, kažejo bolj realno sliko dogodkov v vmesniku *prekrito orodje PVD/obdelovanec* kakor v primeru *statičnih difuzijskih preskusov v vakuumu* brez oksidacije.

3 SKLEPNE UGOTOVITVE

Rezultat difuzije elementov iz orodja in obdelovanca skozi vmesnik je sprememba sestave mejne plasti orodja, ki povečuje možnost mehanskih poškodb rezalnega robu. V primeru odrezovanja s prekritim orodjem te pojave opazimo po daljšem času

titanium oxide along the boundary with the iron there was still some dissolved iron, and on the boundary with the cermet, some dissolved W and Mo. Along the oxide, other elements in the cermet became enriched in the phase rich in nickel and the phase rich in tungsten and molybdenum.

The results of our investigation confirm that layer "C" (boundary layer of the affected tool material) is in every case, extremely rich in Ni, while at the same time in this area we observed a significant drop in the content of Ti, which diffuses through the coating, oxidizes and deposits itself on the coating on the Armco-iron side.

Oxidation and the occurrence of a belt of titanium oxides prevent the normal progress of diffusion between the pure partners: cermet, coating and iron. The formation of an oxidation layer is probably a more realistic phenomenon in cutting than the probability that the surface of the cutter would remain unoxidized at such a high temperature (800 to 1000 ^{o}C). That is why the diffusion experiments carried out in this way show a more realistic picture of the events in the PVD-coated tool/workpiece interface than in the case of static diffusion experiments in vacuum where oxidation was not present.

3 CONCLUSIONS

The result of the diffusion of the elements from the tool and the workpiece through the interface is a change in the composition of the boundary layers of the tool, which increases the possibility of mechanical damage to the cutting edge. In the case uporabe v primerjavi z neprekritim orodjem. Prevleke PVD so difuzijska ovira za atome kisika iz atmosfere, C in Fe iz obdelovanca kakor tudi Ti, Ni, W, Mo in Co ter C iz orodja v material obdelovanca ([10] do [13]).

Obravnavani primer žarjenja difuzijskih členov je razkril nekaj informacij o pojavih, ki se pojavljajo pri odrezovanju železnih zlitin z orodji iz kermeta, prekritih s prevlekami PVD. Opisani poskusi se lahko nanašajo na realni postopek odrezovanja zaradi podobnosti kakor so visoka temperatura, na katero se segreje rezalni rob lokalno ter oksidacijska atmosfera, ki v primeru suhega rezanja v celoti obdaja površino orodja. Neprimerna izbira rezalnih parametrov, ki lahko povzročijo nenavadno visoke temperature rezalnega orodja, so lahko razlog za razgradnjo prevleke PVD, glede na mehanizme, sprožene s spremembami ali pomanjkljivostmi, opisanimi v tem prispevku. Med temi lahko omenimo: spremembe v kemijski sestavi, mikrostrukturne spremembe, napake v novo nastali oksidni plasti (pore, razpoke), notranje napetosti in krhkost. Mehanska nestabilnost oksida na prevleki PVD (nenehno odstranjevanje med odrezovanjem) pospešuje nadaljnjo oksidacijo prevleke PVD in s tem njeno razgradnjo ter povečano obrabo orodja.

of cutting with coated tools these phenomena occur after a longer time of service compared to uncoated ones. PVD coatings are a diffusion barrier to oxygen atoms from the atmosphere, C and Fe from the workpiece as well as for Ti, Ni, W, Mo and Co and C from the tool to the workpiece material ([10] to [13]).

The studied example of annealing diffusion couples has revealed some information on the phenomena that take place in cutting iron alloys with cermet tools coated with PVD coatings. The described experiments can be related to the real process of cutting as there are some similarities such as high temperature, to which the cutting edge heats up locally, and the oxidation atmosphere, which in the case of dry cutting fully surrounds the surface of the tool. Careless selection of cutting parameters, which can cause unusually high temperatures of the cutting tool, may be a reason for the degradation of the PVD coating, according to the mechanisms triggered by the changes or weaknesses described in this contribution. Among these we can mention: changes in the chemical composition, microstructure changes, defects in the newly formed oxide layer (pores, cracks), internal stresses, and brittleness. The mechanical instability of the oxide on the PVD coating (permanent removal during cutting) further accelerates the oxidation of the PVD coating, causing its degradation and increased tool wear.

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