Functional properties of the sintered tool materials with (Ti,Al)N coating

L.A. Dobrzański, L.W. Żukowska, J. Mikula, K. Golombek, P. Podstawski
Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: leszek.dobrzanski@polsl.pl

Received 11.08.2009; published in revised form 01.10.2009

ABSTRACT

Purpose: The paper presents investigation results of functional properties of the sintered tool materials: high-speed steel matrix composites (HSSMC), cemented carbides, cermet and Al₂O₃ type oxide tool ceramics with (Ti,Al)N coating deposited in the cathodic arc evaporation CAE-PVD method and comparing them with the uncoated tool materials.

Design/methodology/approach: Analysis of the mechanical and functional properties: surface roughness, microhardness tests, scratch tests, cutting tests. X-ray qualitative microanalysis of elements.

Findings: Deposition of (Ti,Al)N coating onto high-speed steel matrix composites (HSSMC), cemented carbides, cermet and Al₂O₃ type oxide tool ceramics substrate causes increase of wear resistance as well as reduces the exceeding of steady stresses critical levels. It causes multiple (up to 800%) increase of tool life. As a result of metallographic observations it was stated that linear and uniform character of wear was achieved in case of all deposited samples.

Practical implications: Employment of the hard coatings deposited onto sintered tool materials is reckoned as one of the most important achievements last year in the area of improvement of functional properties of cutting tools.

Originality/value: Combination of substrates (especially coatings deposited on high-speed steel matrix composite) is unique and very interesting in respect of achieved functional properties.

Keywords: Wear Resistance; Coating; Sintered tool materials; Tool life; Cutting test

Reference to this paper should be given in the following way:

1. Introduction

Cutting tool wear is the result of load, friction, and high temperature between the cutting edge and the workpiece. Several wear mechanisms can occur during metal cutting: adhesive wear, abrasive wear, diffusion wear, oxidation wear, and fatigue wear. Typical tool wear model after cutting is presented in Fig. 1. The tribological properties of uncoated tool material never satisfy all performance requirements. Coated tools can generate high wear resistance on the surface with high toughness in the substrate material. Properly applied coatings increase the surface hardness of cutting tools at high cutting temperatures, thus minimizing abrasive wear. The coating provides a chemical barrier to decrease diffusion or reaction between the tools and the workpiece, thus reducing tool wear [1-9, 12-16].

In the development of new, contemporary materials the functionality is often improved by combining materials of
different properties into composites. Coating composites are specifically designed to improve properties such as tribological, electrical, optical, electronic, chemical and magnetic ones. (Ti, Al)N coatings are characteristic for high hardness, good wear-resistance and excellent, high-temperature properties. Therefore, (Ti,Al)N coatings have become popular as hard coatings for tools in recent years [1-11, 17-19].

The goal of this work is to investigate the functional properties of the high-speed steel matrix composites (HSSMC), cemented carbides, cerments and Al2O3 type oxide tool ceramics with (Ti,Al)N coating deposited in the cathodic arc evaporation CAE-PVD method and comparing them with the uncoated tool materials.

2. Methodology of research

Experiments were carried out on high-speed steel matrix composites (HSSMC), cemented carbides, cerments and Al2O3 type oxide tool ceramics with (Ti,Al)N coating deposited in the PVD process which were later compared with the uncoated samples (Table 1).

The Ra surface roughness parameter measurements and observations of surfaces topography of the developed coatings were made on LSM 5 PASCAL confocal microscope.

The Vickers microhardness was measured using the Hanemann tester. The tests were made with the load of 0.98 N, making it possible to eliminate, to the greatest extent, the influence of the substrate material on the measurement results.

Adhesion evaluation of the coatings on the investigated inserts was made using the scratch test on the CSEM REVETEST device, by moving the diamond penetrator along the examined specimen’s surface with the gradually increasing load. The critical load Lc, at which coatings’ adhesion is lost, was determined based on the registered values of the acoustic emission AE.

Cutting ability of the investigated materials was determined based on the technological continuous cutting tests of the EN-GJL-250 grey cast iron with the hardness of about 250 HB (Fig. 2). The wear band VB=0.20 mm wide, on the surface of the tool used for machining, it was the criterion for the cutting edge consumption evaluation. The following parameters were used in the machining capability experiments: feed rate f=0.1 mm/trn, depth of cut a p=1 mm, cutting speed v c=150 m/min. The character of the developed failure was evaluated based on observations made on the light microscope and on the scanning electron microscope and analysis of the chemical composition of the tool wear using the X-ray energy dispersive spectrograph (EDS).

3. Results

Roughness of the substrates defined by R a parameter is within 0.06-0.13 µm range. Depositing (Ti,Al)N coating onto the examined substrates causes increase of the roughness parameter from R a=0.14 µm for the cemented carbide substrates, R a = 0.12 µm high-speed steel matrix composite (HSSMC) and cermet substrates, to R a=0.27 µm for the (Ti,Al)N coating deposited on Al2O3+TiC substrate.

The highest microhardness of the investigated uncoated materials has been stated in case of Al2O3+TiC substrate (2105 HV 0.1) and the lowest for the high speed-steel matrix composite (1150 HV 0.1). Depositing the (Ti,Al)N coating on such substrate results in a significant increase of the surface layer hardness, in the range of 2850-3170 HV 0.1. Therefore, depositing the wear resistant coatings onto the tool high speed-steel matrix composites, cemented carbides, cerments, and oxide tool ceramics results in a significant increase of the surface layer microhardness, contributing in this way in machining to the decrease of the flank wear intensity of cutting tools’ flanks.

The critical load values Lc (AE) were determined using the scratch method with the linearly increasing load (“scratch test”), characterising adhesion of the investigated (Ti,Al)N coating onto high-speed steel matrix composites, cemented carbides, cerments and tool ceramics. The critical load was determined as the one corresponding to the acoustic emission increase signalling beginning of spalling of the coating. The coatings deposited onto the investigated substrates are characterised by good adhesion (Lc = 57.1-69.5 N) (Table 1, Fig. 3). The very good adhesion of (Ti,Al)N coating to cermet substrates is a result of the fact that the source of the nitrogen for the developing coating is not only the working gas, but also nitrogen coming from the substrate alone, making diffusion mixing of elements in the interlayer easier.
Deposition of \((\text{Ti,Al})\text{N}\) coating onto oxide ceramic substrate caused significant increase of tool life measured during cutting tests (Fig. 4). Comparison of the approximated values of the VB wear of the sintered tool materials: uncoated and coated with the \((\text{Ti,Al})\text{N}\) coating, depending on machining time is shown in Figs. 6-9.

In case of machining tests carried out with use of HSSMC and cermet samples, very quick edge fracture occurred (Fig. 10). Deposition of \((\text{Ti,Al})\text{N}\) coating onto HSSMC as well as onto cermet substrates causes increasing of wear resistance as well as reduces the exceeding of steady stresses’ critical levels. It causes multiple (up to 800%) increase of tool life (Figs. 6-8). As a result of metallographic observations it was stated that linear and uniform character of wear was achieved in case of all deposited samples (Figs. 5, 11).

Depending on used substrate material, life period of uncoated tools was in rage of 2 min. in case of tool made of high-speed steel matrix composites, 2.5 min. of tool made of cemented carbides and cermet to 18 min. in case of tools made of oxide tool ceramics. Depositing of investigated \((\text{Ti,Al})\text{N}\) coating onto all used sintered tool materials caused significant increase of tool life measured during cutting tests (Fig. 4). Comparison of the approximated values of the VB wear of the sintered tool materials: uncoated and coated with the \((\text{Ti,Al})\text{N}\) coating, depending on machining time is shown in Figs. 6-9.

In case of machining tests carried out with use of HSSMC and cermet samples, very quick edge fracture occurred (Fig. 10). Deposition of \((\text{Ti,Al})\text{N}\) coating onto HSSMC as well as onto cermet substrates causes increasing of wear resistance as well as reduces the exceeding of steady stresses’ critical levels. It causes multiple (up to 800%) increase of tool life (Figs. 6-8). As a result of metallographic observations it was stated that linear and uniform character of wear was achieved in case of all deposited samples (Figs. 5, 11).

Fig. 3. Comparison of the critical load according to the scratch test of \((\text{Ti,Al})\text{N}\) coating deposited on high-speed steel matrix composites, cemented carbides, cermets and \(\text{Al}_2\text{O}_3\) type oxide tool ceramics

Fig. 4. Comparison of tool life for tools from high-speed steel matrix composites, cemented carbides, cermets, and oxide ceramic with the \((\text{Ti,Al})\text{N}\) coatings

Fig. 5. Character of wear of the high speed-steel matrix composites (HSSMC) sample with \((\text{Ti,Al})\text{N}\) coating, investigated with SEM after cutting test
Deposition of (Ti,Al)N coating onto oxide ceramic substrate causes significant increase of functional properties first of all by changing of the tool wear character, minimization of disadvantageous processes (built-up edge forming and brittle cracking). As a result of metallographic observations it was stated that, in spite of partially delamination of coating deposited onto oxide ceramics, built-up edge forming and brittle cracking was much more lower than in case of uncoated samples. In spite of partially delamination of coating, being most probably an effect of deposition process disturbance, wear of coated sample was uniform (Fig. 16b).

Multiple increase of tool life results among other things from very high increase of microhardness of PVD coated materials in comparison with uncoated HSSMC, cemented carbides, cermets and oxide tool ceramics.

The increase of tool life should be connected with increasing of thermal and chemical wear resistance caused by occurrence of diffusion and thermal barrier. Increasing of tool life is most probably also caused by improving of chip formation and removing the process conditions.

Deposition of (Ti,Al)N coating onto oxide ceramic substrate significantly increases functional properties first of all by changing of the tool wear character, minimization of disadvantageous processes (built-up edge forming and brittle cracking). As a result of metallographic observations it was stated that, in spite of partially delamination of coating deposited onto oxide ceramics, built-up edge forming and brittle cracking was much more lower than in case of uncoated samples. In spite of partially delamination of coating, being most probably an effect of deposition process disturbance, wear of coated sample was uniform (Fig. 16b).

Multiple increase of tool life results among other things from very high increase of microhardness of PVD coated materials in comparison with uncoated HSSMC, cemented carbides, cermets and oxide tool ceramics.

The increase of tool life should be connected with increasing of thermal and chemical wear resistance caused by occurrence of diffusion and thermal barrier. Increasing of tool life is most probably also caused by improving of chip formation and removing the process conditions.
Fig. 8. Comparison of the approximated values of the VB wear of the cermets sample: uncoated and coated with the (Ti,Al)N coating, depending on machining time

Fig. 9. Comparison of the approximated values of the VB wear of the Al₂O₃ type oxide tool ceramics sample: uncoated and coated with the (Ti,Al)N coating, depending on machining time

Fig. 10. (a) Character of wear of the cermets sample uncoated, investigated with SEM after cutting test, (b) the detail of (a)

Fig. 11. (a) Character of wear of the cermets sample with (Ti,Al)N coating, investigated with SEM after cutting test, (b) the detail of (a)

Fig. 12. Character of wear of the cermets sample with (Ti,Al)N coating, investigated with SEM

Fig. 13. X-ray energy dispersive spectrum from the surface of the (Ti,Al)N coating deposited on cermets substrate. Area of point on Fig. 12

Fig. 14. X-ray energy dispersive spectrum from the surface of the (Ti,Al)N coating deposited on cermets substrate. Area of point on Fig. 12

Fig. 15. X-ray energy dispersive spectrum from the surface of the (Ti,Al)N coating deposited on cermets substrate. Area of point on Fig. 12
Properties

y = 0.0231x^3 - 0.1091x^2 + 0.2129x

R^2 = 0.9946

y = 4E-05x^3 - 0.0017x^2 + 0.0272x

R^2 = 0.9545

0 0.05 0.1 0.15 0.2 0.25 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

Time t [min]

Wear VB [mm]

Fig. 8. Comparison of the approximated values of the VB wear of the cermets sample: uncoated and coated with the (Ti,Al)N coating, depending on machining time

Fig. 9. Comparison of the approximated values of the VB wear of the Al2O3 type oxide tool ceramics sample: uncoated and coated with the (Ti,Al)N coating, depending on machining time

Fig. 10. (a) Character of wear of the cermets sample uncoated, investigated with SEM after cutting test, (b) the detail of (a)

Fig. 11. (a) Character of wear of the cermets sample with (Ti,Al)N coating, investigated with SEM after cutting test, (b) the detail of (a)

Fig. 12. Character of wear of the cermets sample with (Ti,Al)N coating, investigated with SEM

Fig. 13. X-ray energy dispersive spectrum from the surface of the (Ti,Al)N coating deposited on cermets substrate. Area of point on Fig. 12

Fig. 14. X-ray energy dispersive spectrum from the surface of the (Ti,Al)N coating deposited on cermets substrate. Area of point on Fig. 12

Fig. 15. X-ray energy dispersive spectrum from the surface of the (Ti,Al)N coating deposited on cermets substrate. Area of point on Fig. 12
coated materials in comparison with uncoated samples, increase wear resistance as well as reduces the exceeding of steady HSSMC as well as onto cermet substrate causes increasing of formation and process conditions removal. 

face, thermal cracks on tool flank, spalling of the cutting edge, investigated materials are as follows: mechanical defects and tribological defect types occurring most often, identified in the carried out on the scanning electron microscope, that the diffusion mixing of elements in the interlayer easier.

of the nitrogen to develop a coating is not only the working gas, coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings deposited onto the investigated substrates are causes the 47-148 % increase of microhardness value. The has been found that (Ti,Al)N coating on the investigated materials coating. As results of the examination of coating microhardness it has been found that (Ti,Al)N coating on the investigated materials causes the 47-148 % increase of microhardness value. The coatings deposited onto the investigated substrates are characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source of the nitrogen to develop a coating is not only the working gas, but also nitrogen coming from the substrate alone, making diffusion mixing of elements in the interlayer easier.

It was found out, on the basis of the metallographic analysis carried out on the scanning electron microscope, that the tribological defect types occurring most often, identified in the investigated materials are as follows: mechanical defects and abrasive wear of the tool flank, development of the crater on tool face, thermal cracks on tool flank, spalling of the cutting edge, and build-up edge from the chip fragments.

Uniform wear model on the tool flank, was observed in case of all coated samples. Deposition of (Ti,Al)N coating onto HSSMC as well as onto cermet substrate causes increasing of wear resistance as well as reduces the exceeding of steady stresses’ critical levels. It causes multiple (up to 800%) increasing of tool life. Such significant increase of tool life results among other things from very high increase of microhardness of PVD coated materials in comparison with uncoated samples, increase of thermal and chemical wear resistance and improvement of chip formation and process conditions removal.

Increase of thermal and chemical wear resistance caused by occurrence of diffusion and thermal barrier, the most important reason is the increase of tool life.

4. Conclusions

The results of the investigations of the high-speed steel matrix composites (HSSMC), cemented carbides, cerments and Al2O3+TiC type oxide tool ceramics coated with the (Ti,Al)N coating with use of the cathodic arc evaporation CAE-PVD method are given in the paper. The results of roughness and microhardness tests confirm the advantages of the (Ti,Al)N coating. The results of the investigations of the high-speed steel matrix composites (HSSMC), cemented carbides, cerments and Al2O3+TiC type oxide tool ceramics coated with the (Ti,Al)N coating. As results of the examination of coating microhardness it has been found that (Ti,Al)N coating on the investigated materials causes the 47-148 % increase of microhardness value. The coatings deposited onto the investigated substrates are characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source of the nitrogen to develop a coating is not only the working gas, but also nitrogen coming from the substrate alone, making diffusion mixing of elements in the interlayer easier.

It was found out, on the basis of the metallographic analysis carried out on the scanning electron microscope, that the tribological defect types occurring most often, identified in the investigated materials are as follows: mechanical defects and abrasive wear of the tool flank, development of the crater on tool face, thermal cracks on tool flank, spalling of the cutting edge, and build-up edge from the chip fragments.

Uniform wear model on the tool flank, was observed in case of all coated samples. Deposition of (Ti,Al)N coating onto HSSMC as well as onto cermet substrate causes increasing of wear resistance as well as reduces the exceeding of steady stresses’ critical levels. It causes multiple (up to 800%) increasing of tool life. Such significant increase of tool life results among other things from very high increase of microhardness of PVD coated materials in comparison with uncoated samples, increase of thermal and chemical wear resistance and improvement of chip formation and process conditions removal.

Increase of thermal and chemical wear resistance caused by occurrence of diffusion and thermal barrier, the most important reason is the increase of tool life.
The increase of tool life is due to the diffusion and thermal barrier formation and process conditions removal. Thermal and chemical wear resistance and improvement of chip coated materials in comparison with uncoated samples result in a significant increase of tool life. Such increases can reach up to 800% and are observed in the case of stresses exceeding critical levels. It causes multiple wear reductions, and the exceeding of steady HSSMC as well as onto cermet substrate causes increasing of all coated samples.

Deposition of (Ti,Al)N coating onto investigated materials is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cermet substrate is a result of the fact that the source characterised by good adhesion. The very good adhesion of PVD coatings to cerme...