Surface Engineering - Applied Research and Industrial Applications
Room Town & Country D - Session G3-WeM

Innovative Surface Engineering for Advanced Cutting and Forming Tool Applications
Moderator: Dr. Christoph Schiffers, CemeCon AG, Germany

8:00am **G3-WeM-1 A Novel AlCr-Based PVD Coating Design for Threading Operation of Super Duplex Stainless Steel*, Qianxi He*,** *J. M. DePaiva, T. K. Filho,* McMaster University, Canada*; F. L. Amorim, R. D.Torres,* Pontificia Universidade Católica do Paraná, Brazil*; G. Fox-Rabinovich, S. C. Veldhuis,* McMaster University, Canada

The application of PVD coating is largely employed in industry to improve the tool performance of cutting tools designed to perform cutting in several distinguished materials. As a result, there is a sharp increase in demand for innovative materials with remarkable qualities. Current developments in unconventional cutting materials show the potential of different coating combinations. Based on recent finds PVD Hard coatings based on Al, Cr and Ti are recommended for the machining of super duplex stainless steel (SDSS). In this work, three different PVD coatings systems were applied for the threading process of SDSS. Monolayer Al50Cr50N, Al60Cr40N, and multilayer Al50Cr50N/Al50Ti45Si5N were deposited on cemented carbide inserts. The present article highlighted the effect of alloying and coating architecture design on the mechanical properties, and wear performance of the cutting tools. Adhesion and oxidation were observed as predominant wear mechanisms, and the tool life was superior once the system was coated by the novelmultilayer Al50Cr50N/Al50Ti45Si5N. In order to understand these results, the effect of different parameters on the mechanical properties of the coatings was presented and discussed.

8:20am **G3-WeM-2 Property and Deposition Technology for Highly Al-Containing AlCrN Coatings by Arc Ion Plating*, Ryosuke Takei*,** *T. Takahashi, S. Kujime,* Kobe Steel Ltd., Japan

AlCrN coating is one of the most widely used hard coatings in cutting tool applications. The cutting performance of the coating is dependent on its Al content. The mechanical hardness, wear resistance as well as oxidation resistance at high temperature are known to be increased with the Al content, and hence exhibits a good performance even at a severe machining condition. This feature is generally accepted at an Al content, i.e., fraction of metallic element of Al and Cr, of about up to 70 at.% for AlCrN coatings deposited by physical vapor deposition such as sputtering and cathodic arc, also referred to as arc ion plating. This is mainly linked to the crystallographic structure and characteristics thereof, in which the metastable cubic phase with the favorable mechanical and thermal properties can be sustained at Al content up to 70 at.% while the more thermodynamically stable hexagonal phase with the poor properties tends to form at a higher Al content above 70 at.%. A deposition technique of highly Al containing AlCrN keeping the cubic phase is believed to be a key for further improvement of the coating performance and hence the tool life of cutting tools.

There are some practical challenges for highly Al-containing AlCrN coatings. As compared to typical transition metals of Ti and Cr for nitride coatings, Al has a low melting temperature of 660°C. Therefore, the use of a binary compound target with a high fraction of Al usually results in emission of a large number of macroparticle, which creates internal defects during film growth and adverse effect on the surface quality of the coatings. Another practical point is to ensure the sufficient adhesion of the coating. Coating adhesion of highly Al-containing AlCrN coating appears to be intrinsically poor as compared to those at less Al content.

In this work, we demonstrate the newly developed coating system of arc ion plating equipped with the deposition technology particularly for highly Al-containing AlCrN coatings. With the combination of a newly developed arc source, etching technology and optimization of deposition process parameters, AlCrN coating at Al content above 70 at.% still exhibiting a good surface quality and adhesion were successfully deposited. The coating deposited were characterized in terms of crystallographic structure, surface morphology, chemical composition, and mechanical properties by XRD, SEM-EDX, and nanoindentation, respectively. In order to investigate the performance of the coatings in application, the coatings were also deposited on typical cutting tools such as end-mills and milling inserts and the cutting performance and wear resistance thereof were evaluated.

8:40am **G3-WeM-3 Challenges and Target-Oriented Paths to Maintenance-Free High-Performance Progressive Dies Using HiPIMS-Coatings*, Martin Hess,*** Robert-Bosch-Str., 5, Germany **INVITED**

Being able to economically manufacture precision contacts in large-scale production of 10 million units or more requires more than just having the correctly designed systems.

In such a challenging environment, it is not only the current trend towards electromobility that is driving up the quantities of electrical components and connectors demanded by the market. The consequence for the stamping tool manufacturers is the demand of continuously increasing tool efficiency with increasing stroke rates of currently up to 3000 strokes per minute. In order to achieve the wear resistance of the progressive dies required for this purpose, low-wear active elements (punches, dies, bending and coining tools, clamps, sliding guides, etc.) are essential for the shortest possible stamping press downtimes. Since wear and tear on a single active part of a complex progressive die can already lead to a, time-consuming and therefore costly, maintenance intervention, wear-resistant coatings of active parts are an even more relevant key factor for the production of electrical contact components with outputs of several millions parts per day, respectively up to several billion (!) parts (e. g. connectors, cellphone parts, etc.) per year and progressive die. In addition to general coating challenges as known from micro tools for machining, topics specifically related to stamping applications such as micro cavities, influence of cutting air, parallel machining of different materials with strongly different strengths in one tool, low artifact coated surfaces etc. will be addressed.

The presentation places a special emphasis on HiPIMS, as the latest HIPIMS coatings used for machining high-strength stainless steel strip (Rm > 1400 N/mm²) achieve for the first time comparable wear resistance or part yield compared to active parts machining high-performance copper alloy strip in parallel in the same progressive die. As a result, the goal of the maintenance-free progressive die – which can contain more than 1000 PVD-coated active parts – is also achieved for tools that produce complex electrical contacts with contact securing high-strength oversprings in one progressive die for production lots in the higher two-digit million range.

9:20am **G3-WeM-5 Oxidation and Wear Behavior of CrAlMoN with Varied Mo-content for Cutting $TiAl_6V_4$,** *K. Bobzin, C. Kalscheuer,* ***Nina Stachowski,*** Surface Engineering Institute - RWTH Aachen University, Germany*; W. Hintze, J. Dege, C. Möller, P. Ploog,* Institute of Production Management and Technology - Hamburg University of Technology, Germany

The cutting of difficult to machine materials such as titanium is still challenging for the machining industry. Materials properties lead to accelerated tool wear and premature failure. In case of the titanium alloy TiAl6V4, the low thermal conductivity of λ = 5.8 W/mK and the low Young's modulus of 110 GPa ≤ E ≤ 140 GPa combined with the high yield strength $R_{p0.2}$ = 870 N / mm^2 cause high temperatures, mechanical loads as well as self-excited vibrations at the cutting edge. The use of uncoated carbide tools is currently state of the art. However, temperature active, self-lubricating physical vapor deposition (PVD) coatings like CrAlMoN already showed first promising results to reduce friction and wear during turning of TiAl6V4. In order to develop an effective coating, it is important to understand the wear development and oxidation behavior as a function of the chemical composition of the coating. In the present study, self-lubricating CrAlMoN coatings with x_{Mo} = 20 at.-%, x_{Mo} = 30 at.–% and x_{Mo} = 40 at.–% in the metal content were investigated on cemented carbide tools. The coatings were deposited by hybrid process combining dcMS and HPPMS. Coating morphology, thickness, chemical composition, indentation hardness, indentation modulus at ϑ = 20 °C, ϑ = 200 °C ϑ = 400 °C and ϑ = 600 °C as well as the oxidation behavior were analyzed. Moreover, wear development after cutting tests using a computer numerical controlled (CNC) lathe with a cutting velocity of v_c = 80 m/min and a feed rate of 0.12 mm were analyzed, after defined cutting intervals of t_c = 5 s, t_c = 10 s, t_c = 20 s t_c = 40 s, t_c = 80 s, t_c = 120 s. Independent of the amount of Mo, all coating variants possessed a dense morphology and a smooth surface topography, as well as a coating adhesion class of HF1 to the cemented carbide tools in Rockwell indentation tests according to DIN 4856. The tests were conducted in the initial state and after heat treatments up to ϑ = 800 °C. With increasing amount of Mo, heat treatment temperature and time, more self-lubricating molybdenum oxides such as MoO_3 and Mo_4O_{11} were detected by Raman spectroscopy subsequently. Therefore, the coating with x_{Mo} = 40 at.–% in the metal content possess the highest amount of molybdenum oxides. After cutting tests on the tool flank surface, also molybdenum oxides were found by Raman spectroscopy. Additionally, it was observed, that the areas of tribochemical reactions at the rake faces show a growing trend with higher amount of Mo in the coating. The level of flank wear land width decreases with increasing amount of Mo.

11:00am **G3-WeM-10 The Significance and Application Area of CVD TiCN/Al_2O_3 based Coatings for Today's Cutting Tools**, ***Christoph Czettl,*** CERATIZIT Austria Gesellschaft m.b.H., Austria*; M. Pohler,* CERATIZIT Austria GmbH, Austria*; N. Schalk, M. Tkadletz,* Montanuniversität Leoben, Austria*; F. Konstantiniuk,* Christian Doppler Laboratory for Advanced Coated Cutting Tools at the Department of Materials Science, Montanuniversität Leobon, Austria **INVITED**

Chemical vapor deposited (CVD) coatings are frequently used for metal cutting applications, especially on indexable inserts. Beside coating systems like TiAlN, TiB_2 or other innovative CVD systems, the TiCN/Al_2O_3 based coatings still play an important role. For turning and milling of cast materials, low carbon steels and martensitic steels these architectures are still the first choice. Thus, recent progress in the development of microstructures and architectures as well as improvements of the deposition techniques are summarized. With their first introduction, in the mid of the 1970's, a huge step in cutting performance could be reached. In the following decades, several optimizations of architecture and deposition techniques were introduced, including the medium temperature process for TiCN, defined growth of α-and κ-Al_2O_3 and highly textured α-Al_2O_3 layers. Modern analytical techniques as well as simulation methods were necessary to create a comprehensive understanding of this coating system and explain why they are still indispensable in industry today. This talk gives an historical overview of the development process of the TiCN/Al_2O_3 coating system until reaching the current state of the art.

11:40am **G3-WeM-12 Indentation and Sliding Contact Testing of Three Laser-textured and PVD-coated Cemented Carbide Tools**, ***Shiqi Fang,*** Saarland University, Germany*; C. Colominas,* Flubetech, S.L., Spain*; C. Pauly,* Saarland University, Germany*; N. Salán, L. Llanes,* Universitat Politècnica de Catalunya, Spain

In this study, a new concept cemented carbide tool is presented with laser-generated abrasive-like protrusions on their machining surfaces that mimic the surface features of diamond or cubic boron nitride abrasives commonly used on honing tools. The novel tools were first surface textured by a picosecond laser, and then the new surface structure was protected by three different PVD ceramic hard coatings. All three nitride-based coatings, i.e., TiSiN-TiAlN, TiSiN-TiAlN-CrN and AlTiN-CrN, differ in the adhesion layer and coating structure. The coating-substrate systems were assessed by means of indenting and sliding contact testing. Experimental methodology included (1) 'passive' Vickers indentation hardness tests, and (2) 'active' machining tests. In both cases, the resulting surface integrity was inspected by using FIB/SEM/EDS. It is found that both laser texturing and coating deposition significantly increased the hardness of the coated cemented carbide. The tool coated by the two-layer film (TiSiN-TiAlN) achieved the best performance, in terms of both hardness enhancement and damage prevention experienced under both tests. Meanwhile, improvement was much less pronounced by the two-layer (AlTiN-CrN) coated tool. Here, cracks appeared under the Vickers indentations and the film was completely or partially spalled-off at some protrusion tops (cutting fronts), due to the concentrated stress during the machining. Finally, the three-layer coating with the TiSiN on the top (TiSiN-TiAlN-CrN) exhibited an intermediate response, where moderate hardness increase was combined with some wear – although less severe than for AlTiN-CrN film - taking place at critical points, such as cutting fronts.

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