Surface Engineering - Applied Research and Industrial Applications
Room Palm 1-2 - Session IA3-TuA

Innovative Surface Engineering for Advanced Cutting and Forming Tool Applications

Moderators: Markus Esselbach, Oerlikon Balzer, Liechtenstein, **Dr. Christoph Schiffers**, CemeCon AG, Germany

1:40pm **IA3-TuA-1 Natural Rock Star: PVD-Functionalizing of Nature-Derived Materials for Cutting Applications***, Wolfgang Tillmann,* ***Dominic Graf [dominic.graf@tu-dortmund.de]****, Nelson Filipe Lopes Dias,* TU Dortmund University, Germany*; Bernd Breidenstein, Berend Denkena, Benjamin Bergmann, Hilke Petersen,* Leibniz Universität Hannover, Germany

The manufacturing process of traditional cutting materials such as cemented carbide involves significant energy consumption and costly raw materials that are often linked to environmental harm during extraction. To address these concerns, there is a growing demand for developing sustainable cutting materials. In this context, natural materials are both environmentally friendly and abundant. Natural rocks, in particular, are promising due to their hardness, which typically ranges from 8 to 16 GPa depending on the rock type. The suitability of these natural materials for machining can be enhanced via functionalization of the surface properties by applying a protective thin film using physical vapor deposition (PVD) technology.

Preliminary studies show the suitability of various rock types as cutting material. Cutting inserts are crafted from these natural rocks and subsequently ground. A TiN thin film is deposited onto the various natural rock inserts using a magnetron sputtering process. The resulting TiN thin films crystallize in a cubic structure on all rock types. The obtained hardness values are comparable to TiN thin films grown on tool steel. In contrast to a polished surface, a ground surface of the natural rocks promotes good adhesion of the TiN thin films. To assess the cutting performance and wear characteristics of PVD-coated natural rocks, turning tests are conducted using the aluminum alloy Al7075. The TiN thin film significantly enhances wear resistance, thus extending the service life of the cutting inserts. Additionally, it is observed that the distinct material properties of the natural rocks significantly affect the wear behavior. Rock types with a more homogeneous structure demonstrate improved wear resistance over extended cutting lengths.

To analyze the effect of the substrate on the TiN thin film adhesion three different glass substrates were chosen as surrogates for natural rocks. Glasses are particularly suitable as surrogates because of their similar SiO2 content. The investigations reveal a strong influence of the stress state on the adhesion, as TiN on window glass shows weaker adhesion due to high compressive residual stresses. The possible adaptation of thin film design strategies developed for glass onto natural rock surfaces is evaluated. The utilization of a PVD-coated natural rock emerges as a promising concept for broadening the spectrum of cutting materials and promoting sustainability in their manufacturing. A tailored adjustment of the grinding process for cutting inserts with an adapted thin film design is anticipated to further elevate the cutting performance of natural rock inserts.

2:00pm **IA3-TuA-2 Properties and Metal Cutting Performance of High Entropy Nitride (HEN) and HEN-MN Coatings***,* ***Abhijit Roy [abhijit.roy@kennametal.com]****, Brittany Macshane,* Kennametal Inc., 1600 Technology Way, Latrobe, PA 15650, USA*; Joern Kohlscheen,* Kennametal GmbH, Altweiherstr. 27, 91320 Ebermannstadt, Germany*; Dev Banerjee,* Kennametal Inc., 1600 Technology Way, Latrobe, PA 15650, USA

Hard and wear protective coatings are normally deposited on cutting tools to improve their metal cutting performance and lifetime. These coatings, depending on metal cutting conditions and workpiece materials, often require specific properties which are difficult to achieve by conventional (using binary, ternary or quaternary) nitride coatings. High entropy nitride (HEN) coatings, with disordered multi-cations sublattice and ordered anionic sublattice, show many remarkable properties including high thermal stability induced by entropy stabilization, high hardness, and fracture toughness originating from multiple-elemental lattice distortions and impeded dislocations, as well as excellent corrosion resistance caused by sluggish diffusion. Moreover, multilayer and superlattices of HEN containing layers allow an additional degree of design-flexibility to improve fracture toughness and other properties. This work investigated crystalline structure and morphology, residual stresses, adhesion, mechanical properties and metal cutting performance of cathodic arc plasma deposited thin films of HEN and HEN-MN. The HEN target contains five different elements from groups IV, V and VI of the periodic table and the target for MN contains a single transition metal element. X-ray diffraction results indicate presence of two NaCl type FCC phases for both the single layer HEN and multilayer HEN-MN coatings. The residual compressive stress value of the films does not change much with increase in deposition bias voltages. Nanohardness values of the films were found be in the range of 32-35 GPa and bulk modulus values of the multilayered HEN-MN coatings were slightly higher than the single layered HEN coatings. No correlation was found between the scratch adhesion or indent adhesion strength and substrate bias voltages. Scanning electron microscopy (SEM) images of the coatings show deposition of dense HEN coatings and formations of nanolayers in case of HEN-MN coatings. The elemental analysis using energy dispersive x-ray (SEM-EDX) indicates formation of nitrogen deficient sub-stoichiometric nitrides for both the single layer HEN and multilayer HEN-MN coatings. Turning tests with coated carbide inserts using IN718 as workpiece material showed promising tool life compared to conventional AlTiN coatings.

2:20pm **IA3-TuA-3 Surface Engineering of AlCrN-Coated Carbide through Laser Texturing for Performance Enhancement***,* ***Yassmin Seid Ahmed [yassminm66@gmail.com]****,* KFUPM, Saudi Arabia

Utilization of coating and surface texturing techniques combines to great effect to further enhance the overall performance of carbide surfaces. For these materials, adhesion is most critical in defining the performance of the coating. Poor adhesion and coating quality can lead to eventual failure. With cemented carbide being one of the materials of concern, LST has gained much attention as having superior mean coating adhesion. However, the effects of the combined processes of coating followed by texturing and texturing followed by coating and their interactions remain poorly understood.

This study analyzes micro-structured coated cemented carbide surfaces prepared from varying processes and property conditions while examining their surface characteristics and friction performance. The performance of the substrates, which had undergone surface treatments followed by ball-on-disk tests, was then evaluated and compared. The coated surface sample, where surface texturing was done first and coating applied afterward (AC), showed better microhardness, more refined microstructures, and better wear resistance than the coating surface first, followed by surface texturing (BC). Although the sample coated was found to show superior hardness values across the board, the AC sample displayed more favourable results in other areas. A prime example is that the AC sample was 12% more microhard than the coating sample, although the overall hardness was reduced by 3%, coupled with a reduction in friction force by 8%.

It creates an insightful mark to realize that the order of application of the texturing and coating processes would bear significant relevance in affecting the final performance of the material. This study now stresses that enhanced adhesion and wear resistance were found in the coating substrate wherein the texturing technique was performed first and then coated (AC) as being very consistent in proposing that these combined techniques can make way into producing contributions toward more durable and effective coatings for industrial usages.

2:40pm **IA3-TuA-4 Advanced Cyclic Load Resistance of AlXN Coatings for Metal Forming Applications***,* ***Simon Evertz [simon.evertz@eifeler-vacotec.com]****, Stefan A. Glatz, Tobias Oellers, Markus Schenkel,* voestalpine eifeler Vacotec GmbH, Germany

Cyclic loading is critical for the industrial application of PVD coatings, especially in metal forming applications. With the increasing interest in using thin super-high-strength steel sheets for forming bodies/parts with reduced component weight, light-weight design and less fuel consumption could be achieved for example in automotive industry. Consequently, the loads become more demanding on molding dies and therewith protective coatings. These applications require coatings resistant to cyclic mechanical and/or thermal loading and fatigue. The specific structure of voestalpine eifeler's Duplex-VARIANTIC® -1400-plus with its multiple hard material AlXN layers overcomes the very demanding requirements in terms of strength, hot-hardness, and load-bearing capacity in such metal forming applications and outperforms other commercially used hard nitride protective coatings. This property profile makes voestalpine eifeler's Duplex-VARIANTIC®-1400-plus the optimal solution for metal forming high-strength and advanced high-strength steel sheets.

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