Surface Engineering - Applied Research and Industrial Applications

Room On Demand - Session G3

Innovative Surface Engineering for Advanced Cutting and Forming Tool Applications

G3-1 Enhancing the Performance of Rake and Flank Surface Textured Ceramic Tool Filled With Solid Lubricants*, **Sathiya Narayanan Nagarajan (sathyasairam89@gmail.com)**, S. Venkata Sai Prabhu, S. G, A. G, S. N,* Sastra Deemed University, India

Non-hazardous, toxic-free, allergic-free and less cost-orientated methods are expected by the industries and the industrial workers for the better working-environment. In this work, an effort is made to achieve this expectation by integrating the concept of surface texturing and extended self-lubrication for machining grey cast iron materials. Cross-chevron and line textures were fabricated on the tool's rake and flank faces using Nd: YAG laser texturing machine. An untextured ceramic tool (UT), cross-chevron and line textured tool (TT) and solid lubricants (MoS_2 and Graphite) and SAE 40 oil mixed chemical solutions filled textured tool (STL) are considered for machining under dry conditions. The particles' average size was observed to be 1400 nm and 1590 nm for MoS_2 and graphite solid lubricants, whereas the polydispersity index (PdI) found to be 0.903 and 0.977 respectively. The solid lubricants' PdI values indicated that the particle samples were larger in size distribution and polydisperse. The experimental results observed with the reduced main cutting force, feed force, average friction co-efficient for semi-solid lubricant filled texture tool than other considered tools.

G3-2 Characterization of Different AlCrN PVD Coatings Deposited into H13 Steel for Lube-free Aluminum Die Casting Application*, **Nelson Delfino de Campos Neto (ndelfino@mymail.mines.edu)**, A. Korenyi-Both, S. Midson, M. Kaufman,* Colorado School of Mines, USA

In the high-pressure die casting process, organic lubricants are sprayed onto the die surface prior to each shot to prevent the liquid aluminum from soldering and sticking to the steel die. The organic-based lubricants act as a parting agent, but also produce several undesirable outcomes including: i) reducing the quality of the castings by increasing the amount of entrapped gasses, ii) increasing production costs, and iii) producing effluents that must be treated and discarded. However, portions of the die that become extremely hot, such as small core pins, are difficult to lubricate, and so PVD coatings are often applied to these areas to assist in minimizing soldering. Ideal PVD coatings for die casting applications must exhibit excellent adhesion to the die substrate, have good mechanical and tribological properties, high oxidation resistance, and exhibit chemical inertness to and/or be non-wetting by liquid aluminum.

Recent research at the Colorado School of Mines examined whether PVD coatings could be used to minimize or eliminate the use of conventional organic lubricants during die casting, and a test was developed to quantitatively measure the adhesion strength of aluminum die casting alloys solidified against PVD coated steel substrates. Three PVD coatings (AlCrN, AlTiN and CrWN) were identified where the aluminum die casting alloy exhibited zero adhesion strength to coated substrates. To evaluate the performance in a commercial die casting environment, an entire H13 steel die was PVD coated with AlCrN, and the testing demonstrated that the PVD coating enabled a reduction in the required amount of conventional lubricant spray by around 85%.

To further reduce or eliminate the use of conventional lubricants, coatings with improved non-wetting behavior need to be identified. In the present study, three different AlCrN-based PVD coatings have been examined, and characterization techniques have been used to determine their structure, mechanical properties, wear resistance and adhesion resistance to molten aluminum alloys. This study has demonstrated that small differences in the AlCrN coating can led to appreciably improved performance.

G3-3 12 µm in PVD with HiPIMS*, **Christoph Schiffers (christoph.schiffers@cemecon.de)**, T. Leyendecker, W. Kölker,* CemeCon AG, Germany

Higher coating thickness gives higher wear volume. Today's standard in tool coatings is 3-4 µm. More than 6 µm is for traditional coating technologies not a viable option due to excessive intrinsic stress. No real improvement are the usual work arounds such as bond coats and multilayers with soft intermediate layers. The process gets slower and more prone to failures. A dense morphology with low compressive stress is needed.

HiPIMS is a good candidate since it is known for a dense structure without any droplets resulting in toughness and hardness at the same time. The real innovative leap is stress management by synchronising the HiPIMS pulses on the cathodes with the substrate bias. This paper will introduce the concept of selective ion biasing. Plasma analytics reveal that the flux arriving at the substrate per HiPIMS pulse is composed of the wanted metal ions coming from the target and other ion portions which highly influence the intrinsic stress of the growing film. Selective ion biasing is a fully new tool and allows to precisely select certain ion portions out of the pulse while suppressing unwanted species. Now the coating developer can actively tune the intrinsic stress of the film by setting the synchronisation parameters.

Full control on the process and the growing film – that's the quantum leap of selective ion biasing. And this for different HiPIMS frequencies and pulse data for each and every cathode – tailored for the respective target material.

A case study of FerroCon®Quadro as a 12 µm PVD coating illustrates how HiPIMS moves the frontiers of the possible in tool coatings. Applications such as the milling of crank shafts, railway tracks and heavy duty turning show the enormous performance benefit of very thick PVD coatings for cutting tools. 12 µm PVD work, in HiPIMS.

G3-4 Cross-sectional Characterization of Microstructural, Phase and Elemental Changes during High-Temperature Oxidation of AlCrSiN Coatings*, **Nikolaus Jäger (nikolaus.jaeger@unileoben.ac.at)**,* Christian Doppler Laboratory for Advanced Synthesis of Novel Multifunctional Coatings at the Department of Materials Science, Montanuniversität Leoben, Leoben, Austria*; S. Spor,* voestalpine eifeler-Vacotec GmbH, Düsseldorf, Germany*; M. Meindlhumer,* Christian Doppler Laboratory for Advanced Synthesis of Novel Multifunctional Coatings at the Department of Materials Science, Montanuniversität Leoben, Austria*; H. Hruby, F. Nahif,* voestalpine eifeler-Vacotec GmbH, Düsseldorf, Germany*; C. Mitterer,* Montanuniversität Leoben, Austria*; J. Keckes,* Erich Schmid Institute for Materials Science, Austrian Academy of Sciences, Leoben, Austria*; R. Daniel,* Christian Doppler Laboratory for Advanced Synthesis of Novel Multifunctional Coatings at the Department of Materials Science, Montanuniversität Leoben, Austria

Increasing demands in machining and forming industry towards advanced applications such as dry cutting or high-speed machining stimulate the development of coatings with enhanced properties to protect the surface of tools and workpieces under extreme conditions. Besides substantial requirements on the mechanical properties, also thermal stability and oxidation resistance play a key role in high-temperature applications.

In this work, the high-temperature oxidation of AlCr(Si)N coatings with 0, 2.5 and 5 at.% Si-content was studied. Differential scanning calorimetry together with thermogravimetric analysis and ex-situ X-ray diffraction revealed a shift of the on-set temperature for oxidation from 1100°C for AlCrN to 1260 °C for both Si-containing coatings and a much slower oxidation progress for the latter due to their nanocomposite microstructure. In addition to these conventional characterization methods, an AlCrSiN coating with 5 at.% Si was partially oxidized at 1400 °C for 1 h and studied along its cross-section to investigate microstructural and elemental changes during high-temperature oxidation.

X–ray nano-diffraction of the sample cross-section revealed the formed phases, residual strain state and structural variations across the coating thickness: (i) A dense oxide layer at the surface comprising mainly of Al2O3 and Cr2O3 protected the coating from further oxidation. (ii) Below this oxide layer, a fine-grained transition zone with incomplete oxidation was found. (iii) The bottom half of the coating was not oxidized and consisted only hexagonal AlN.

A detailed TEM analysis allowed for a better understanding of the microstructural and elemental changes during oxidation and revealed: (i) a separation of the oxide layer into an Al-rich and a Cr-rich part, (ii) a strong outwards diffusion of Cr into the oxide layer and (iii) a pronounced separation of the not oxidized part of the coating into Al-rich and a Si-rich grains.

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