Tribology and Mechanics of Coatings and Surfaces
Room Town & Country A - Session MC-ThP

Tribology and Mechanics of Coatings and Surfaces Poster Session

MC-ThP-1 Evaluation of Stress Field in a Borided Inconel 718 Superalloy Under Dry Sliding Wear, *Alan Daniel Contla Pacheco, Iván Campos Silva,* Instituto Politécnico Nacional, Mexico*; Arturo Ocampo Ramírez,* Universidad Veracruzana, Mexico*; Daybelis Fernández Valdés,* Tecnológico Nacional de México*; GERMAN ANIBAL RODRIGUEZ CASTRO,* ***Felipe Nava Leana [felnaval@gmail.com]****, ALFONSO MENESES AMADOR,* Instituto Politécnico Nacional, Mexico

In this work, the wear resistance of Inconel 718 superalloy hardened by the boriding process was evaluated by means of dry sliding. A powder-pack boriding process was used to modify the alloy surface in which nickel borides were obtained in the sample due to the boron diffusion into the substrate material. The thermochemical treatment was carried out at a temperature of 950 °C for 2 and 6 h of exposure time. The Ni2B, Ni4B3 and Ni3B intermetallic compounds formed on the surface of the Inconel 718 superalloy were confirmed by XRD analysis. Berkovich nanoindentation tests were conducted to determine both hardness and Young's modulus of the borided samples. The dry sliding wear tests were performed on the surface of the borided sample using an alumina ball with diameter of 6 mm, a constant load of 20 N and distances of 50, 100, 150 and 200 m. Wear coefficient was obtained by the Archard's model. The finite element method using mesh nonlinear adaptivity was used to obtain the stress field during the wear test. Results of the failure mechanisms over the worn tracks showed that the sample with thicker thickness had better wear resistance.

MC-ThP-3 Tribological and Corrosion Performance of Alloy 718 coated with WC/Co Applied by HVOF, ***Nathalia Kappaun Vieira [nathaliakapp@hotmail.com]****,* PUCPR, Brazil*; Steffen Aicholz,* Oerlikon Balzers, Brazil*; Michelle Sostag Meruvia, Paulo Soares, Ricardo Diego Torres,* PUCPR, Brazil

Nickel-based superalloys, such as Inconel 718 and Inconel 625, are widely used in oil and gas industry due to their mechanical and Chemical properties. The extraction and processing environments involve high temperatures, high pressures, and corrosive environments. Nickel alloys offer high mechanical strength at elevated temperatures, and excellent resistance to corrosion and oxidation, ensuring safety and a longer service life for components that use them. Inconel 718 has high corrosion resistance, but its application is limited due to low hardness and wear resistance. One method of solving this problem is to combine heat treatment with application of coatings. The present work carried out a comparative study of the tribological and tribocorrosive properties of nitride Inconel 718 and Inconel 718 with a WC/Co coating, applied by the HVOF method, which was chosen due to the obtention of a dense layer with low porosity, improving the wear resistance of the material. The surfaces were characterized using X-ray diffractometry (XRD), microhardness, and scanning electron microscopy (SEM) techniques. The tribological, tribocorrosive, and corrosive properties were evaluated in five environments: (a) Distilled water saturated with CO2; (b) distilled water with sodium chloride; (c) distilled water saturated with H2S; (d) distilled water with sodium chloride and saturated with CO2; (e) distilled water with sodium chloride, CO2and H2S. Where in the end the surfaces will be compared across three requirements: i) corrosion current and potential, ii) wear rate, iii) wear rate considering the synergistic effect of tribocorrosion.

MC-ThP-4 Influence of Coating Thickness and Bias Voltage on Cracking Behavior of TiAlCrN PVD Coating, *Kirsten Bobzin,* ***Christian Kalscheuer [kalscheuer@iot.rwth-aachen.de]****, Wenting Xu,* Surface Engineering Institute - RWTH Aachen University, Germany

Physical Vapor Deposition (PVD) TiAlCrN coatings show outstanding mechanical properties, thermal stability and oxidation resistance. Therefore, TiAlCrN coatings exhibit great potential to be deposited on cutting tools in order to minimize wear during cutting operations. Both the coating thickness and the bias voltage applied during the PVD process can influence the cracking behavior of the coating, which in turn affects the machining capacity and lifetime of the cutting tools. In this study, TiAlCrN coatings with thicknesses of s = ~ 2.2 µm, ~ 2.8 µm and ~ 3.8 µm were deposited on cemented carbide WC-Co substrates under a constant applied bias voltage of U_B = -80 V. In addition, TiAlCrN coatings were deposited with different applied bias voltages of U_B = -60 V, -80 V and -100 V at a constant thickness of s = ~ 2.8 µm. The cracking resistance was evaluated using nanoscratch tests with constant forces of F = 250 mN, 500 mN and 750 mN. A conical diamond indenter was used for the nanoscratch tests. Nanoscratches were analyzed for cracks on the surface and in cross-section for coating deformation using scanning electron microscopy (SEM). Additionally, the depth of the nanoscratches were measured with confocal laser scanning microscopy (CLSM). In this study, thicker coatings exhibit better cracking resistance. With increasing thickness, the permanent deformation is reduced. In addition, the coating deposited with a bias voltage of U_B = -100 V exhibits the lowest deformation. The results reveal valuable insights in the cracking behavior of TiAlCrN coatings. These findings can contribute to enhancing the machining performance and the lifetime of cemented carbide tools through targeted coating design.

MC-ThP-5 Enhancing Corrosion Resistance and Tribological Performance of Inconel 718 through Plasma Nitriding and CrAlN/DLC Coatings for Oilfield Applications, ***Heloísa Scalabrin [heloisa.scalabrin@pucpr.edu.br]****, Michelle Sostag Meruvia, Paulo Soares, Ricardo Diego Torres,* Pontifícia Universidade Católica do Paraná (PUC-PR), Brazil

Oil and gas environments are highly corrosive due to the presence of H_2S, CO_2, and chloride ions, which accelerate material degradation through both chemical and mechanical mechanisms. This study investigates the impact of plasma nitriding on the tribological performance, adhesion, and corrosion resistance of CrAlN/DLC coatings deposited on Inconel 718 substrates. The goal is to develop an alternative surface treatment suitable for extreme oilfield conditions.

The Inconel 718 specimens were aged at 760 °C for 6 hours. Three groups were analyzed: (i) nitrided Inconel 718, (ii) nitrided Inconel 718 with CrAlN/DLC coating, and (iii) Inconel 718 with CrAlN/DLC coating without nitriding. Characterization was conducted using nanoindentation to assess mechanical properties, pin-on-disk testing for wear evaluation, and scratch testing for adhesion. The tribocorrosion performance was evaluated in a simulated oilfield environment. Structural and phase integrity of the coatings were analyzed using Raman spectroscopy and X-ray diffraction (XRD), while surface morphology and failure mechanisms were examined via scanning electron microscopy (SEM).

Plasma nitriding enhances surface hardness and promotes the formation of a diffusion layer, which improves coating adhesion and compatibility with the substrate. This combination reduces friction and wear under tribocorrosive conditions. Additionally, DLC deposition lowers friction coefficients and wear rates, further enhancing resistance to tribocorrosion. Preliminary results indicate that nitriding significantly increases surface hardness and coating adhesion. XRD analysis confirms the structural integrity of CrAlN/DLC coatings after exposure, supporting the proposed surface treatment as a multifunctional solution for harsh oilfield environments.

MC-ThP-6 High Temperature Stability of Different Diamond-Like Carbon Thin Films, ***Daniel Pölzlberger [daniel.poelzlberger@tuwien.ac.at]****,* Institute of Materials Science and Technology, TU Wien, Austria*; Julien Keraudy, Klaus Böbel,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; Tomasz Wojcik, Philip Kutrowatz,* Christian Doppler Laboratory for Surface Engineering of High-performance Components, TU Wien, Austria*; Carsten Gachot,* Institute of Design Engineering and Product Development, Research Unit Tribology, TU Wien, Austria*; Helmut Riedl,* Institute of Materials Science and Technology, TU Wien, Austria

The transition to a more energy-efficient world requires innovative solutions, with materials science and tribology playing critical roles. Improving lubrication and reducing wear are essential for lowering the carbon footprint, conserving energy, and meeting climate targets. While conventional liquid lubricants perform well under many conditions, extreme environments, such as high or cryogenic temperatures, high contact pressures, vacuum, or radiation, demand the use of solid lubricants combined with advanced materials. However, many solid lubricants, including MoS_2, MXenes, and graphite, oxidize rapidly above approximately 400 °C, limiting their applicability. Developing self-lubricating materials that also provide excellent corrosion and wear resistance is, therefore, crucial. Among solid lubricating coatings, diamond-like carbon (DLC) is one of the most established. Yet, its performance at high temperatures above 400 °C remains questioned, as DLC coatings are suspected to degrade under such conditions. A systematic comparison and extreme condition testing that links tribological performance to coating properties is still missing.

This study investigates different DLC-based thin film materials, classifying them by dominant mechanisms, application ranges, and performance.

Several DLC coatings are compared, including non-hydrogenated DLC (a-C), hydrogenated DLC (a-C:H), hydrogenated DLC with an oxide former (a-C:H:Si:O), and tetrahedral amorphous carbon (ta-C). These coatings, which vary in mechanical properties and sp_2/sp_3 ratios, were tribologically tested at different temperatures and loads. Subsequent surface characterization included nanoindentation, Raman spectroscopy to analyze the effects of graphitization after thermal exposure, and X-ray photoelectron spectroscopy. Further insights into the limits of carbon as a solid lubricant are provided through high-resolution characterization techniques such as high-resolution transmission electron microscopy.

In summary, this work highlights the potential of advanced DLC coatings for solid lubrication. It highlights the need for a deeper understanding of their mechanisms and the design of innovative coatings to enable future high-performance applications.

MC-ThP-7 The Impact of Nitriding Parameters on the Tribological and Corrosion Behavior of Inconel 718, *Gabriel Queiroz Carara, Heloisa Scalabrin, Cesar Neitzke, Michelle Meruvia, Paulo Soares,* ***Ricardo Torres [ricardo.torres@pucpr.br]***, PUCPR, Brazil

The mechanical and tribological properties, along with the corrosion resistance of plasma-nitrided Inconel 718, were evaluated at nitrided treatment temperatures of 400°C and 500°C. The treatments varied in duration, lasting 1 hour, 2 hours, or 4 hours, and utilized gas compositions of 5% N_2 / 95% H_2 and 25% N_2 / 75% H_2 at a pressure of 530 Pa. Microstructural characterization was conducted using X-ray diffraction. For mechanical characterization, Vickers hardness measurements were performed using a force of 245.2 mN. The tribological properties were assessed through a reciprocating wear test involving an Inconel 718 and cemented ball pair, from which the wear rate was determined. Corrosion resistance was evaluated through potentiodynamic polarization testing. The results indicated that treatment at 400°C led to the formation of the expanded austenite phase, while the samples nitrided at 500°C formed the CrN phase. As anticipated, increasing the nitriding parameters resulted in a progressive increase in sample hardness—from 4.5 GPa for untreated samples to 9.75 GPa for those treated at 500°C with 25% N_2 for 4 hours. A notable reduction in the coefficient of friction was observed in all nitrided samples compared to the non-nitrided sepecimen, with the samples treated at 500°C exhibiting the lowest friction coefficient values. Additionally, the wear rate saw a significant decrease when comparing nitrided samples to non-nitrided ones.

MC-ThP-9 Effect of Sodium Tungstate on the Wear and Corrosion Behavior of Micro-Arc Oxidation Coatings on AZ31 Magnesium Alloy, ***Yueh-Lien Lee [yuehlien@ntu.edu.tw]***, National Taiwan University, Taiwan

Magnesium alloys offer advantages such as low density and high specific strength, but their practical application is often limited by insufficient wear and corrosion resistance. Micro-arc oxidation (MAO) is a promising surface treatment for modifying surface characteristics of magnesium alloys. In this study, MAO coatings were formed on AZ31B magnesium alloy using a silicate-based electrolyte, with and without the addition of boric acid.

Coatings were prepared in a boric-acid-free electrolyte and in electrolytes containing 2 g/L and 5 g/L boric acid, respectively. The influence of boric acid addition on coating morphology, discharge behavior, and wear- and corrosion-related characteristics was examined. The results indicate that the presence of boric acid alters the MAO discharge behavior and coating formation, leading to observable differences in coating compactness and surface features. Variations in wear response and electrochemical impedance behavior were observed among the coatings prepared under different electrolyte conditions.

At higher boric acid concentrations, changes in discharge intensity were associated with increased coating porosity, which influenced wear and corrosion behavior. Additional electrolyte modification was explored to assess the effect of conductivity on coating characteristics. These results provide preliminary insight into the role of boric acid in controlling MAO coating formation and wear–corrosion behavior on AZ31B magnesium alloy.

MC-ThP-10 Advantages of Ultra–High Vacuum Tribology, ***Esteban Broitman [ebroitm@hotmail.com]***, *Sven Kelling, Rickmer Kose,* Sentys Inc., USA

Tribological behavior —friction, wear, and adhesion— depends strongly on the local environment. In air, adsorbed water, oxygen, and organics form boundary films that dominate contact mechanics; reducing pressure thins these films and shifts interactions toward intrinsic solid–solid processes. Ultra–high vacuum (UHV, below 10^{-9} mbar) effectively removes physisorbed monolayers on laboratory timescales, exposing atomic–scale adsorption, chemisorption, cold–welding, and intrinsic wear mechanisms otherwise masked at higher pressures. UHV tribology is therefore critical for vacuum–service industries (space mechanisms, semiconductor tools, accelerators, vacuum MEMS), yet remains rare because of specialized chambers, rigorous bakeout, vacuum–compatible instrumentation, and long pumpdown cycles. Commercial UHV tribometry options are limited; **PREVAC** currently offers a commercial UHV tribometer reaching ~10^{-9} mbar. This review synthesizes UHV studies, compares UHV, HV, and atmospheric results for common materials and coatings, and issues practical recommendations to improve industrial uptake and reproducibility.

MC-ThP-11 Influence of Boriding Time on the Wear Behavior and Structural Stability of Ti6Al4V Under Simulated Physiological Conditions, ***J. A. Nieto-Sosa [jnietos2100@alumno.ipn.mx]***, *M. A. Melo-Pérez, I. Arzate-Vázquez, L. A. Moreno-Ruíz,* Instituto Politécnico Nacional, Mexico; *E.E. Vera-Cárdenas,* Tenológico Nacional de México/Instituto Tecnológico de Pachuca, Mexico; *G. A. Rodríguez-Castro, J.A. Andraca-Adame, Josué Escobar-Hernández,* Instituto Politécnico Nacional, Mexico

This work evaluates the tribological performance of Ti6Al4V alloy modified via powder pack boriding for potential use in high-load biomedical implants. The study investigates the mechanical response and structural stability of biphasic TiB_2/TiB layers exposed to two distinct simulated physiological environments: Hanks' solution and Simulated Body Fluid (SBF), providing a comprehensive insight into the performance of these surfaces in ionic media. Mechanical characterization revealed that the boriding process at 1100 °C for 5 and 20h significantly increases surface hardness, reaching a range of 1900 to 3600 HV for the titanium boride phases. Interfacial integrity was assessed via Rockwell C adhesion tests (VDI 3198), showing a transition from HF3 to HF4 as treatment time increased to 20 h. This shift reflects a highly compressed and hardened surface state that maintains structural integrity without coarse delamination during mechanical contact. The reciprocating sliding results highlighted a reduction in the steady-state Coefficient of Friction (CoF), dropping from 0.40 for the untreated alloy to 0.22 (5 h) and 0.12 (20 h). A significant contrast was observed between the biological fluids: SBF proved to be more aggressive than Hanks' solution, inducing a 15% increase in the specific wear rate (k) and higher signal tortuosity due to increased ionic activity and chloride-mediated interaction. Despite this, the 20 h condition (28.2 µm thickness) achieved a 97.6% reduction in k (1.60 x10^{-6} mm^3/Nm) compared to the untreated reference (61.87 mm^3/Nm). Morphological analysis via optical profilometry confirmed that the boride layers do not fail by traditional material removal. Instead, they exhibit a sinking-in effect, where the hard ceramic layer is pressed into the thermally softened substrate. This mechanism was quantified through the Plastic Deformation Ratio (PDR), which decreased from 0.33 in the untreated alloy to 0.05 in the 20 h condition. These findings demonstrate that a 20 h boriding treatment is critical to providing the necessary load-bearing capacity and dimensional stability required for orthopedic applications in iogenic environments.

MC-ThP-12 Vapor Deposition Coatings for Hard Chrome Replacement in Advanced Mechanical Components, ***Giacomo Bernardelli [256293@studenti.unimore.it]***, *Luca Lusvarghi, Giovanni Bolelli,* Universita degli Studi di Modena e Reggio Emilia, Italy; *Alessio Bassano,* Leonardo S.p.A., Italy

Metallic chromium coatings produced by electrochemical deposition starting from hexavalent chromium oxide (CrO3) are widely employed due to their excellent mechanical and tribological properties. However, Cr6+ substances have been classified cancerogenic for many years. Therefore, according to European Union REACH regulation, they cannot be used in Europe without a temporary authorization. Chrome platers must apply for reauthorization before the old one expires. In this context, in collaboration with Leonardo S.p.A. alternative deposition technologies are being investigated to replace Cr6+ plating for mechanical components currently treated with this process. A further challenge in this path towards safety and sustainability is imposed by the European Union through a list of Critical Raw Materials (CRMs), which combine raw materials of high importance to the EU economy and of high risk associated with their supply. Therefore, the alternative coatings materials used with hexavalent Cr-free deposition processes should also exclude CRMs.

The selected technology is PVD in a MS configuration, using Cr targets to obtain Cr-based films. The substrate is a quenched and tempered alloy steel comparable to that used in the final application. The primary goal of the work was to get reasonably thick coatings (>10 µm) on planar samples and then refining the coating architecture to improve mechanical and tribological performance. Specifically, a comparison is made between two sample sets fabricated using the same deposition technique, with variations in the process parameters.

Nanoindentation and scratch testing were used to analyse mechanical characteristics and adhesion and ball-on-disc tests were used to examine tribological behaviour. A rather dense coating structure was identified by morphological investigations, obtaining high hardness values (about 1300 HV), surpassing those of ordinary hard chromium. Excellent adherence was shown in scratch testing, and no coating delamination was seen within the applied load range (20 mN–30 N). Ball-on-disc tests against Al_2O_3 balls showed relatively low wear rates in the range of 10^{-6} to 10^{-7} mm/N·m and a relatively low friction coefficient (~0.4).

These results are encouraging toward the improvement of the coating architecture and the development of a deposition technology which could be applied by the company to achieve a complete replacement of hexavalent chromium in their applications.

MC-ThP-14 Temperature–Driven Tribofilm Evolution in Oscillating Sliding Contacts Revealed by Advanced Surface Characterization*, Florian Pape,* Bruker Inc., USA*; Alexander Dulebo, Udo Volz,* ***Ude D. Hangen [ude.hangen@bruker.com]****,* Bruker Nano GmbH, Germany

Tribofilms are essential for reducing friction and wear in mechanical systems, directly influencing efficiency and component lifetime. To investigate additive–driven tribofilm formation, oscillating sliding tests were conducted on a Bruker UMT TriboLab using a 6 mm 100Cr6 steel ball against silicon and steel substrates. A base oil with 5% ZDDP, known for promoting phosphate–based tribolayers, and 1 wt% graphene platelets was used to study friction behavior and film growth.

Experiments were run on pristine silicon under a 2 N normal load, 2 mm stroke, 2 Hz frequency, for 15 minutes at temperatures of 25–30°C, 70°C, and 100°C. The resulting wear tracks were examined using complementary Bruker instruments. A stylus profiler quantified topographical changes and tribofilm height variations. Mechanical properties of the resulting layers and its friction were characterized with high spatial resolution using the Bruker Hysitron TI–990 TriboIndenter. Nanoscale mapping of surface structures and mechanical contrast was performed on a Bruker Dimension Icon AFM operating in PeakForce QNM mode, enabling visualization of additive–derived features inside and outside the wear scars.

This combined characterization approach provides detailed insights into how ZDDP and graphene additives influence tribofilm formation under oscillating contact, supporting the development of more effective lubricant systems for advanced tribological applications.

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