Tribology and Mechanics of Coatings and Surfaces
Room Golden State Ballroom - Session MC-ThP

Tribology and Mechanics of Coatings and Surfaces Poster Session

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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-2 Electro-Tribological Behavior of Borided Steels in Lubricated Sliding–Rolling Contacts, ***Leonardo Farfan-Cabrera [farfanl@tec.mx]***, Tecnologico de Monterrey, Mexico*; Peter Lee, Carlos Sanchez,* Southwest Research Institute, San Antonio Texas, USA*; Cesar Resendiz Calderon,* Tecnologico de Monterrey, Mexico*; Ali Erdemir, Merve Uysal Komurlu,* Texas A&M University, USA

The electric vehicle drivetrains are subject to new tribological challenges caused by stray electricity leading to surface degradation and lubricant breakdown. This work explores the potentials of boridingtreatment as a dual-function approach to enhance not only the electrical but also tribological properties of rolling–sliding components under lubricated and electrified conditions. Recent studies have shown that borided layers can exhibit high hardness, chemical stability, and inherently low electrical conductivity, making them attractive candidates for the production of low-cost insulating gears and bearing systems; however, their traction behavior under lubricated and electrified conditions has not yet been explored. In this study, AISI 52100 bearing steel discs and balls were thermochemically borided to form Fe_2B/FeB layers and tested in a mini-traction machine (MTM) under slide-to-roll ratios from 0–20% and entrainment speeds between 0.001 and 3900 mm/s which are typical of bearing operating regimes. Each test matrix consisted of twelve consecutive runs (six speed and six traction tests) conducted at 20 °C and 75 °C under 0, 1.5, and 3 A DC using a PAO base oil and a fully formulated ATF. Surface characterization was performed by optical profilometry, SEM, Raman and XRD spectroscopy to examine the influence of electrification and lubrication on the tribochemical response of borided layers. Overall, this study provides a framework to assess the potential of boriding as an insulating surface treatment for bearings in next-generation e-mobility systems.

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-8 Microstructural and Mechanical Characterization of Plasma-Nitrided Mig-Welded h13 Tool Steel, ***Gabriel Ossovisck [gabriossov@gmail.com]***, *Gelson de Souza,* Universidade Estadual de Ponta Grossa, Brazil; *Hipolito Carvajal-Fals,* Universidade Tecnológica Federal do Paraná, Brazil; *Guilherme Valadão,* Universidade Estadual de Ponta Grossa, Brazil; *Anderson Pukasiewicz,* Universidade Tecnológica Federal do Paraná, Brazil; *Roger Verástegui,* Universidade Tecnológia Federal do Paraná, Brazil; *Milton Polli,* Universidade Tecnológica Federal do Paraná, Brazil; *Francisco Serbena,* Universidade Estadual de Ponta Grossa, Brazil; *Higor Prochno,* Universidade Tecnológica Federal do Paraná, Brazil

This study investigates the effects of plasma nitriding (400 °C, 3 h, 50% N_2–50% H_2) on MIG-welded H13 tool steel, comparing the microstructural and phase evolution between the weld zone and the base metal. Specimens with dimensions of 10 mm × 10 mm × 20 mm were prepared through precision grinding, polishing and ultrasonic cleaning prior to nitriding.

After nitriding, optical microscopy investigations revealed a clear microstructural distinction between the base and welded regions, with structures typically associated with the high cooling rates in weld beads. The nitrided layers were characterized by X-ray diffraction (XRD) to identify the phases formed during treatment. The analysis confirmed the presence of characteristic nitrided phases (γ'-Fe_4N, ε-Fe_3N, CrN, and Cr_2N) in both regions, though significant differences in nitrogen retention were observed. The Fe_4N and CrN peaks were markedly more intense in the weld region, suggesting enhanced nitrogen incorporation.

Elemental mapping (EDS) of both the weld and base regions after nitriding revealed the presence of silicon- and chromium-rich intermetallic precipitates, as well as a distinct nitrogen diffusion profile characterized by a steep concentration gradient. Nitrogen-rich zones, when compared with the iron maps, indicated that the coexistence of nitrogen, chromium, and molybdenum promotes the formation of compounds with reduced iron content.

This altered diffusion behavior is consistent with the presence of retained austenite in the weld region compared with the base material — a consequence of the rapid cooling during welding — which enhances nitrogen penetration depth while reducing near-surface concentration. These findings are corroborated by comparative EBSD phase analyses.

Nanoindentation measurements confirmed differences in the mechanical behavior of the nitrided layers between the base and welded samples. In both cases, the surface hardness was significantly higher than the untreated substrate, reaching values of approximately 1,313 HV for the welded region and 1,400 HV for the base material.

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