Tribology and Mechanics of Coatings and Surfaces
Room Town & Country B - Session MC3-3-FrM

Tribology of Coatings and Surfaces for Industrial Applications III

Moderators: Osman Eryilmaz, Argonne National Laboratory, USA, **Volker Weihnacht**, Fraunhofer IWS, Germany

8:00am **MC3-3-FrM-1 High-performance ta-C-based coatings for tribological applications deposited by laser-arc technique***, **Volker Weihnacht [volker.weihnacht@iws.fraunhofer.de]**, Frank Kaulfuss, Stefan Makowski, Falko Hofmann, Fabian Härtwig, Martin Zawischa,* Fraunhofer IWS, Germany **INVITED**

Tetrahedral amorphous carbon (ta-C) coatings are increasingly used in tribological contacts and can be found in numerous industrial applications due to their wear resistance caused by super hardness in combination with generally low friction. Fraunhofer IWS has developed a deposition technique for stable industrial coating processes for ta-C using a pulsed, laser-triggered arc discharge on graphite cathodes. The laser-arc technique can be combined with plasma filtering to reduce the density of particle-induced defects in the ta-C coatings. In addition to the further development of plasma filter technology, IWS has currently focused on the development of doped ta-C(:X) coatings by using graphite composite cathodes. In this contribution, it will be shown how doping affects the deposition behavior as well as the structure and properties of the grown ta-C:X coatings. Special emphasis is placed on the tribological properties using various engine oils and alternative, environmentally friendly lubricants.

8:40am **MC3-3-FrM-3 The Development of Amorphous-Based Multi-Component Alloys for the Nanocomposite Coatings and their Properties***, **Kyoung Il Moon [kimoon@kitech.re.kr]**, Gi hoon Kwon, Hae Won Yoon, Byoungho Choi, Kyong jun An,* Korea Institute of Industrial Technology, Republic of Korea*; Sung Chul Cha,* Hyundai Motor Group-Hyundai Kefico, Republic of Korea

While modern industries are becoming more sophisticated, diversified, and globalized, they requires the development of smart materials have multi-functionality, high mechanical properties, and extreme durability. Also they could be prepared environmentally friendly and energy efficiently. At the same point of view, the smart coating materials capable of simultaneously expressing various mechanical properties or opposite properties such as high hardness with high toughness, high electricity with high corrosion resistance are attracting attentions as an versatile and useful materials in the future. In particular, there is an urgent needs to develop a novel coating materials capable of stably maintaining microstructures and mechanical properties in various external environments, unlike conventional coating materials whose properties and structures are easily changed by the some harsh environments. To get this kinds of objects, the coating material with multi-components are essential. But if the materials should be prepared with one phase with multi components, they could have only one properties. So, nano-composites with various phases should be formed to realize the various properties. So, it is necessary to develop a coating layer composed of various components those could be formed various phases and more complex structures with multifunctional properties.

In this study, various single alloy target materials with various compositions based on the Zr-Cu amorphous materials have been prepared by powder metallurgy methods such as atomization, mechanical alloying, and Spark Plasma Sintering (SPS). The various nanocomposite coatings could be prepared by using single alloying targets. The most important property is the composition of the target material could be transferred to the coating layers. The properties of as-prepared nanocomposite coatings will be summarized in this present including the coating's performance under conditions that simulate EV drivetrain environments.

9:00am **MC3-3-FrM-4 Corrosive Wear Mechanisms and Corrosion Performance of WC-Reinforced Fe–iN625 Coatings Fabricated by Laser Cladding***, **Yiqi Wang [suzyiqi@gmail.com]**,* Northeastern University, China

Marine components are frequently exposed to seawater, where simultaneous mechanical wear and corrosion significantly reduce service life, highlighting the need for coatings with combined wear and corrosion resistance. In this work, WC-reinforced Fe–IN625 composite coatings with 0–10 wt.% WC were fabricated on ductile iron via laser cladding to enhance hardness, wear resistance, and corrosion–wear performance in marine environments. The novelty of this study lies in quantitatively elucidating the dual role of WC particles as heterogeneous nucleation sites that refine dendritic microstructure and as rigid load-bearing reinforcements that stabilize tribofilms under coupled corrosion–wear conditions.Microstructural analysis revealed W-rich dendrites around WC particles, and increasing WC content to 10 wt.% formed a secondary carbide network, raising surface microhardness from 278 HV (0% WC) to 352 HV (10% WC), a 26.6% increase. Under dry sliding, the friction coefficient decreased from 0.63 (S1) to 0.46 (S3), and wear volume decreased from 35,075 $\times 10^{-6}$ cm^3 to 24,756 $\times 10^{-6}$ cm^3, a 29% reduction. In 3.5 wt.% NaCl solution, corrosion current density dropped from 3.87×10^{-4} A/cm^2 (S1) to 1.15×10^{-6} A/cm^2 (S3), while polarization resistance increased from 19.67 $k\Omega\cdot cm^2$ to 55.25 $k\Omega\cdot cm^2$, reflecting the formation of a dense protective passive film.In combined corrosion–wear tests, the 10 wt.% WC coating (S3) exhibited a wear rate of 4.14×10^{-4} N^{-1}, markedly lower than 8.25×10^{-4} N^{-1} for the substrate and 5.77×10^{-4} N^{-1} for the WC-free coating (S1), while maintaining a stable friction coefficient around 0.13–0.15. WC particles acted as a rigid skeleton to share applied loads, and Ni–Cr-rich tribofilms reduced adhesion and abrasive damage, synergistically improving corrosion-assisted wear resistance.Overall, the 10 wt.% WC-reinforced coating achieved the highest hardness, lowest dry and corrosive wear, minimal friction fluctuation, and maximal corrosion protection. This study provides a quantitative framework linking WC content, microstructural refinement, and coupled corrosion–wear behavior, offering a design strategy for durable Fe–IN625 coatings in marine and harsh corrosive environments.

9:20am **MC3-3-FrM-5 Effect of Boriding on the Surface Hardness and Wear Resistance of Low Carbon Steel Fabricated by Wire Arc Additive Manufacturing (WAAM)***, **Abraham Molina-Sanchez [A01363512@tec.mx]**, Cesar David Resendiz-Calderon, Leonardo Israel Farfan-Cabrera, Christian Ricardo Cuba-Amesquita,* Tecnológico de Monterrey, Mexico

Wire and Arc Additive Manufacturing (WAAM) enables the production of large-scale, geometrically complex components at a significantly lower cost compared to other additive manufacturing (AM) technologies. It offers extensive material availability, including low-carbon steel, which is widely used in mechanical and structural components. However, due to its low hardness and corrosion resistance compared to other steels, its use is limited in high-demand environments. This study evaluates the effect of boriding on the surface hardness and wear resistance of low-carbon steel fabricated using the WAAM technique. WAAM-built low-carbon steel plates were printed layer by layer to complete 60 layers per sample using ER70S-6 steel wire (0.8 mm diameter). The parameters included a welding voltage of 19.7 V, 67 A current, 5 mm/s travel speed, and a shielding gas of 100% CO_2 supplied at 15 L/min. These samples were subjected to a boriding process wherein a sealed container with Ekabor 2 powder as the boron donor was used, heated at 950°C for 3 hours, and cooled at room temperature. A boride layer with an average thickness of 93.5 ± 32.6 µm composed of FeB and Fe_2B phases was formed, as confirmed by X-ray diffraction (XRD). The adhesion of the boride layer on the as-built (AB) samples was evaluated using a progressive scratch test, and nanoindentation revealed an increase in hardness with no significant changes along the material deposition direction. Dry-sliding tests measured the coefficient of friction (CoF) between AB and borided samples, and a considerable wear volume decrease of 20% was observed with the boride layer, as measured by optical profilometry. These results demonstrate no significant changes along the build direction in phase composition, hardness, or tribological behavior, indicating that boriding is an effective surface treatment for enhancing wear resistance in WAAM-fabricated low-carbon steel.

10:20am **MC3-3-FrM-8 Ultralow Wear, Conductive Plasma-Enhanced Atomic Layer Deposited Metal Nitrides***, **Brandon Krick [bkrick@eng.famu.fsu.edu]**,* Florida State University, USA **INVITED**

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