

## ABSTRACT

The present research work explores the effect of microstructural and phase evolution attributed to the variation in heat input and coating thicknesses during coating deposition via atmospheric plasma spraying on wetting, corrosion, wear, and tribocorrosion behavior of Fe-based amorphous/nanocrystalline composite (Fe-ANC) coatings. Cr and Mo promote corrosion resistance of the alloy while B, C, and P improve GFA and increase the hardness, thereby contributing to superior wear and corrosion performance of the alloy. Feedstock powder of the above alloy composition, synthesized via water atomization, was used to deposit coatings under varying spraying parameters, such as plasma powers and coating thicknesses. Two coating thicknesses, viz.  $170 \pm 15 \mu\text{m}$  and  $425 \pm 25 \mu\text{m}$  thick, were selected to systematically investigate the influence of heat input and layer build-up on coating microstructure and properties. Detailed microstructural and phase characterization, such as scanning electron microscopy (SEM), X-ray diffraction (XRD), differential scanning calorimetry (SDC), and transmission electron microscopy (TEM) revealed that all coatings exhibited an amorphous/nanocrystalline composite structure. Increasing heat input and coating thickness resulted in a gradual reduction in porosity and surface roughness due to improved splat flattening, enhanced particle melting, and pore filling by subsequent torch passes. Simultaneously, higher heat input and thicker coatings promoted more in-situ crystallization within the amorphous matrix, leading to the formation of nano-sized intermetallic phases. The amorphous fraction was found to decrease with increasing plasma power and coating thickness, consistent with both XRD and DSC analyses.

Wettability studies demonstrated that the wetting behavior of the coatings was strongly governed by surface roughness and porosity. For lower-thickness coatings ( $170 \pm 15 \mu\text{m}$ ), an optimum plasma power of 30 kW resulted in improved hydrophobicity and enhanced corrosion resistance, whereas further increase in plasma power to 40 kW led to deterioration in

performance due to excessive crystallization. In contrast, higher-thickness coatings ( $425 \pm 25$   $\mu\text{m}$ ) exhibited a monotonic increase in contact angle with increasing plasma power as a result of reduced porosity and suppressed capillary action. However, despite improved hydrophobicity, corrosion resistance decreased at higher plasma powers due to the dominant influence of increased crystallinity. Among all investigated conditions, the coating deposited at 20 kW with a thickness of  $425 \pm 25$   $\mu\text{m}$  exhibited superior corrosion resistance, highlighting the importance of balancing wettability and phase composition.

Tribological investigations revealed that coatings deposited at higher heat input exhibited enhanced hardness and wear resistance, primarily due to reduced porosity and the presence of nano-sized hard intermetallic phases embedded within the amorphous matrix. Wear behavior was found to be strongly dependent on the mode of sliding. Rotating wear tests resulted in lower specific wear rates and coefficients of friction compared to reciprocating wear, attributed to reduced debris accumulation and lower peak kinetic energy of the counter body. A clear transition in wear mechanism was identified, from fatigue-dominated wear under reciprocating motion to abrasion-dominated wear under rotating motion. A systematic investigation of dry sliding wear parameters using design of experiments and analysis of variance established sliding speed as the most significant factor influencing wear rate, followed by applied load and sliding distance. Higher sliding speeds led to increased wear due to elevated flash temperatures, oxidation-assisted delamination, and enhanced kinetic energy at the contact interface. Tribocorrosion studies conducted in 3.5 wt.% NaCl solution demonstrated that short-duration wet sliding reduced wear due to the lubricating effect of the electrolyte, whereas prolonged exposure resulted in accelerated degradation as corrosion effects surpassed lubrication. Multiple wear mechanisms were identified, with fatigue dominating under dry conditions and abrasion combined with corrosion prevailing under wet sliding conditions.

This study established the process–microstructure–property relationships in plasma-sprayed Fe-based amorphous coatings and demonstrates that careful control of spraying parameters enables the optimization of wear and corrosion performance. The findings contribute to the broader understanding of Fe-based amorphous coatings and present a promising pathway for developing robust, cost-effective surface protection coatings

Keywords: Fe-based amorphous coating; Atmospheric plasma spraying; Surface roughness; Wetting behavior; Corrosion behavior; Reciprocating wear; Rotating wear; Wear mechanism; Passive film; Transition in wear mechanism; Tribocorrosion