Tailoring microstructure for enhanced performance: low-current PTAW deposition of NiCrBSi coatings

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Abstract

Statement of the Problem: In the pursuit of advancing performance and extending the lifespan of machine tools, parts, and components for a sustainable future, the utilization of cutting-edge surface engineering technologies, such as coating deposition, is crucial. To tackle the challenges related to wear and corrosion in mechanical engineering systems, directed energy deposition (DED) coating fabrication methods like laser cladding and plasma transferred arc welding (PTAW) are commonly employed to apply thick coatings onto the target substrate. However, these processes often rely on high currents, typically exceeding 100 A, leading to unfavorable conditions such as electrode degradation and excessive heat generation, posing risks of flammability to users and the environment, thus compromising sustainability. This research delves into the use of lower currents, specifically in the range of 60 A to 70 A, within the PTAW process to deposit NiCrBSi coatings onto a structural steel substrate. The objective is to address the challenges associated with wear and corrosion. By carefully adjusting both the standoff distance and the PTA currents, ranging from 60 A to 70 A, the microstructure of the coatings, which possess a face-centered cubic (FCC) structure, was tailored to overcome these challenges.

Conclusion & Significance: The study achieved enhancements in the coatings' transgranular capabilities by reducing geometrically necessary dislocation (GND) densities and promoting the evolution of Nickel γ-fiber texture components within densely packed {111} planes at a specific orientation distribution function (ODF) angle of $\varphi_2 = 45°$. Remarkably, an increase in texture volume fractions was observed as the process current decreased. Furthermore, improvements in the coatings' intergranular capabilities were attained by increasing the volume of low-angle grain boundaries (LAGBs) and special low coincidence site lattice (Σ-CSL) boundaries, particularly those within the range of $3 < \Sigma < 29$. The findings highlight enhanced resistance to corrosion and wear in the coatings, especially with decreasing current, resulting in a coating hardness of up to 754 $HV_{0.5}$.

Image

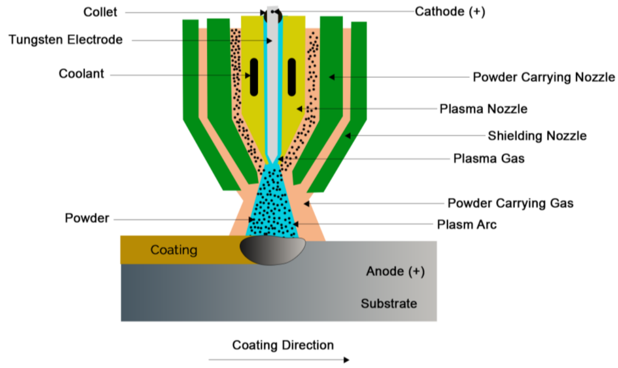

Figure 1. Schematic diagram of coaxial powder-feeding plasma transferred arc welding process.

Recent Publications

1. Appiah, A., Wyględacz, B., Matus, K., Reimann, Ł., Bialas, O., Ferreira Batalha, G., Czupryński, A., & Adamiak, M. (2024). Microstructure and performance of NiCrBSi coatings prepared by modulated arc currents using powder plasma transferred arc welding technology. *Applied Surface Science*, *681*, 1–16. https://doi.org/10.1016/j.apsusc.2023.159065
2. Appiah, A., Bialas, O., Czupryński, A., & Adamiak, M. (2022). Powder plasma transferred arc welding of Ni-Si-B+60wt%WC and Ni-Cr-Si-B+45wt%WC for surface cladding of structural steel. *Materials*, *15*, 1–23. https://doi.org/10.3390/ma15144956
3. Appiah, A., Bialas, O., Żuk, M., Czupryński, A., Sasu, D. K., & Adamiak, M. (2022). Hardfacing of mild steel with wear-resistant Ni-based powders containing tungsten carbide particles using powder plasma transferred arc welding technology. *Materials Science-Poland*, *40*, 42–63. https://doi.org/10.2478/msp-2022-0033
4. Adamiak, M., Appiah, A., Żelazny, R., Ferreira Batalha, G., & Czupryński, A. (2023). Experimental comparison of laser cladding and powder plasma transferred arc welding methods for depositing wear-resistant NiSiB + 60% WC composite on a structural-steel substrate. *Materials*, *16*, 1–25. https://doi.org/10.3390/ma16113912
5. Adamiak, M., Appiah, A. N. S., Woźniak, A., & Bialas, O. (2024). Surface modification of metallic materials using laser and plasma technologies. In T. A. Kovács, Z. Nyikes, T. Berek, N. Daruka, & L. Tóth (Eds.), *Critical infrastructure protection in the light of the armed conflicts* (pp. 81–91). https://doi.org/10.1007/978-3-031-47990-8_8

Photograph

Biography

Mr. Augustine Nana Sekyi Appiah is currently pursuing a PhD at the Silesian University of Technology in the field of Materials Engineering. His research focuses on exploring sustainable approaches to materials design and fabrication, with a particular emphasis on leveraging additive manufacturing technologies such as powder bed fusion (PBF) and plasma-assisted directed energy deposition (DED).

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