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Wear Performance and Optimization of hBN-Modified AZ91/TiB_2 Magnesium Composites Under Dry Sliding Conditions

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The present study focuses on the development and tribological evaluation of AZ91 magnesium matrix composites reinforced with TiB_2 and hexagonal boron nitride (hBN) nanoparticles. The TiB_2 content was fixed at 6 wt%, while hBN was varied at 0.5, 1, 1.5, and 2 wt.% to examine its influence on wear performance. The composites were fabricated using the stir casting technique, followed by tribological testing under dry sliding conditions. The wear experiments were designed based on an L16 Taguchi orthogonal array, incorporating variations in normal load, sliding speed, and sliding distance. To establish predictive insights, Gradient Boosting Regression (GBR) was employed to estimate wear rate and friction coefficient, effectively capturing nonlinear dependencies between input parameters. Further, Multi-Objective Particle Swarm Optimization (MOPSO) was applied to determine the optimal combination of reinforcement content and test conditions for minimizing wear and friction while maintaining mechanical integrity. The results indicate that the hybrid composite with optimized hBN content exhibits enhanced wear resistance, attributed to the combined effects of solid lubrication and microstructural reinforcement. The self-lubricating nature of hBN reduces frictional heating and surface damage, whereas TiB_2 contributes to load-bearing capability and matrix strengthening. Experimental validation confirmed a strong correlation between predicted and observed values, demonstrating the reliability of the proposed modeling approach. This study highlights the potential of machine learning-driven optimization in designing advanced Mg-based composites for applications in aerospace, biomedical, and automotive industries, where high wear resistance and lightweight materials are critical.

Keywords: Magnesium Matrix Composites, Hexagonal Boron Nitride (hBN), Tribological Performance, Gradient Boosting Regression (GBR), Multi-Objective Particle Swarm Optimization (MOPSO)