

Microstructural characterization, wear and corrosion behaviour of High-Entropy Hardmetal coatings deposited by HVOF

Lorenzo Miconi

Department of Materials and Environmental Engineering, University of Modena and Reggio Emilia, Modena, Italy

High Entropy Hardmetals (HEHMs) are emerging as sustainable materials for wear- and corrosion-resistant thermal spray coatings. In the CoBrain project, multiple TiC-based hardmetals with high entropy alloy (HEA) matrices were studied. Co-free matrix compositions were selected from the Al-Cr-Cu-Fe-Mn-Mo-Ni-Si system using a machine learning (ML)-based tool which was trained on the results from both computational modeling and laboratory tests in order to predict features such as phase composition, stacking fault energy, and hardness. The phase evolution of the HEA matrices was double-checked with the Thermo-Calc CalPhaD software to verify the predicted phase composition. Dry sliding wear tests were performed at room temperature using a high-temperature ball-on-disk tribometer with an alumina counterpart. The most resistant materials were also tested up to 800 °C in the same configuration. Three body high-stress abrasion tests were performed with the steel wheel method using alumina as abrasive. The coatings' microstructure and wear mechanisms, the phase composition, and the nature of the thermally grown oxide layer were characterized by FEG-SEM and optical profilometry, X-ray diffraction, and Raman spectroscopy, respectively. Additionally, microhardness measurements and scratch tests were carried out to further evaluate the micro-mechanical properties of the coatings. Electrochemical polarization tests in 3.5% NaCl solution were carried out to evaluate the corrosion resistance of the coatings. The wear rates and the corrosion behaviour of the coatings were compared to those of a WC-CoCr and a Cr₃C₂-NiCr coatings, obtained from commercially available powders.

Most of the coatings exhibited dense, crack-free microstructures with minimal oxide inclusions. All the coatings matrices were found to have simple crystalline structure, as expected from the Thermo-Calc simulation and the ML prediction. A single-phase FCC matrix, with its ductility, helped to limit the occurrence of micro-pitting by brittle fracture during sliding wear at room temperature. However, the coatings with a higher Fe content also showed significant matrix amorphization after deposition and, consequently, high brittleness, which impaired the room-temperature sliding wear resistance. At high temperature, Mo-containing compositions exhibited better sliding wear resistance through the formation of a molybdate-containing tribofilm. In general, the wear rates measured on the HEHM coatings were higher than that of WC-CoCr at room temperature, but better than Cr₃C₂-NiCr at all temperatures. The corrosion current densities measured in the electrochemical polarization test, on the other hand, were comparable to WC-CoCr, but worse than Cr₃C₂-NiCr.

The results demonstrate that TiC-based HEHMs are promising candidates for industrial applications requiring a good balance of wear performance and corrosion resistance, though some improvements are still needed.