MS-4-P-5826 Microstructural characterization of detonation sprayed MMC coatings

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In thermal spraying of powders, deposition in the solid state is accompanied by intensive plastic deformation; deposition of fully or partially molten particles proceeds through the splat formation and particle dispersion upon impact. Thermal action on the powder particles can cause chemical interactions of the powders with the gaseous environment and between the phases of the composite materials. Due to involvement of several physical and chemical phenomena, the microstructure development in thermally sprayed coatings is a complex process while the coatings are challenging objects for Electron Microscopy. In our investigations, we use Scanning and Transmission Electron Microscopy to study the microstructure of detonation sprayed metal matrix composite (MMC) coatings. Their phase composition is either inherited from the powders or evolves during spraying. In the TiB2-Cu system, we found that the size of the titanium diboride particles depends on the O2/C2H2 ratio increasing with increasing O2 content in the mixture. The ceramic reinforcement in TiN-Ti, TiCN-Ti and titanium oxides-Ti MMC coatings formed in situ as a result of chemical reactions of titanium with the gaseous phase during spraying, the coatings possessing a layered hierarchical structure composed of the matrix metal and the reaction products (Fig.1). The Ti3SiC2-Cu system is of great interest, as it can be sprayed in both solid and molten states. In the latter, reaction Ti3SiC2 + Cu → TiC + Cu(Si) occurs. We have shown that it is possible to preserve the Ti3SiC2-Cu phase composition in the coatings only in cold conditions of detonation spraying — at an explosive charge of 30% of the barrel volume at O2/C2H2=1.1. Calculations show that the temperature of copper particles 40 μm in size sprayed under these conditions does not reach the copper melting point (Fig.2). Chemical etching of the polished surface of the cross-sections of the coatings helped us better reveal the microstructural features of the coatings. In the coating deposited at an explosive charge of 30%, the lines reflecting the microstructural features of the Ti3SiC2-Cu powder agglomerates produced by mechanical milling show random orientation (Fig.3). This indicates solid-state deposition of the Ti3SiC2-Cu composite particles. In the coating deposited at an explosive charge of 40%, these lines have preferential orientation parallel to the coating/substrate interface (Fig.4) indicating the presence of a characteristic layered structure formed by partially molten composite particles.

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Fig. 1: Cross-section of the titanium oxides-Ti coating produced by detonation spraying of titanium at $\text{O}_2/\text{C}_2\text{H}_2=2.5$ and air as a carrier gas, BSE image.

Fig. 2: Calculated temperatures of detonation sprayed copper particles $40 \, \mu\text{m}$ in size upon leaving the gun barrel at different explosive charges ($\text{O}_2/\text{C}_2\text{H}_2=1.1$; carrier gas – air).

Fig. 3: Cross-section of the coatings produced by detonation spraying of the Ti$_3$SiC$_2$-Cu composite powder (etched in FeCl$_3$ solution; the coating/substrate boundary is horizontal): $\text{O}_2/\text{C}_2\text{H}_2=1.07$, explosive charge 30%, BSE image.

Fig. 4: Cross-section of the coatings produced by detonation spraying of the Ti$_3$SiC$_2$-Cu composite powder (etched in FeCl$_3$ solution; the coating/substrate boundary is horizontal): $\text{O}_2/\text{C}_2\text{H}_2=1.07$, explosive charge 40%, BSE image.