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Microstructure formation in plasma-sprayed functionally graded NiCoCrAlY/yttria-stabilized zirconia coatings

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Abstract

Functionally graded NiCoCrAlY/yttria-stabilized zirconia coatings were fabricated by plasma spraying using mechanically alloyed, plasma-spheroidized NiCoCrAlY/yttria-stabilized zirconia (YSZ) composite powders. Scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS) analysis revealed that oxidation of aluminum, chromium and yttrium in the NiCoCrAlY alloy occurred in the high-temperature plasma-spray stream during powder preparation and coating deposition. The oxidized products, predominantly aluminum oxide, subsequently mixed with zirconia at elevated temperatures in a wide composition range. These mixtures are observed as fine lamellae structures with different gray levels in the back-scattered electron (BSE) mode. Among the lamellae structures, the regions containing high aluminum oxide concentration appeared darker, compared with the regions with high zirconia concentration. It was observed that aluminum oxide formed a preferential combination with zirconia in the coating. Dendritic structures were frequently observed in the coating interlayers and were considered to have formed during the solidification process of the molten splats. The observations on polished cross-sections also showed that the resultant coatings were dense and had no clear interface between adjacent layers. It is believed that the graded distribution of the coating compositions helped to decrease the high level of residual thermal stresses experienced during thermal cycling, and hence contribute positively to the bond strength of the coating. These functionally graded coatings have demonstrated superior tensile adhesive bond strength to duplex coatings.

Keywords: Functionally graded material; NiCoCrAlY alloy; Plasma spray; Thermal barrier coating; Yttria-stabilized zirconia

1. Introduction

In jet engines, gas turbines and diesel engines, many components are coated with thermal barrier coatings (TBCs) to provide high thermal resistance and reduce the metal surface temperatures, thus increasing component durability. The thermal barrier coating material used most commonly is yttria-stabilized zirconia (YSZ). This material has been investigated intensively in recent years [1–6].

In TBC applications, YSZ coatings are normally deposited together with a bond coat. NiCrAlY [7] or NiCoCrAlY [8] is employed as an oxidation-resistant metallic bond coat. Besides oxidation, the thermal mismatch between the YSZ coating and metallic materials is another severe problem that causes failure. Coatings of functionally graded materials (FGMs) can effectively reduce the discontinuities in thermal expansion coefficients between coating and metallic substrate in order to avoid mismatch-related failure in service. Functionally graded coatings can also resist surface cracking [9].

Compared with the duplex thermal barrier coating, which contains a nickel alloy bond coat and a YSZ top coat, a functionally graded coating contains intermediate layers where the bond-coat alloy and top-coat ceramic are mixed in various ratios. Thus, a gradual change in composition and microstructure from the bond-coat layer to the YSZ top-coat layer is achieved [10].

To form functionally graded thermal barrier coatings through plasma spraying, either co-injection of the two different powders in a single plasma torch [11,12] or multiple-torch spray deposition [12] can be applied. However, it is not easy to control the spray parameters to form a uniform coating layer, as the two kinds of starting powder may have different densities, sizes, morphologies, melting point and flowability. In our study we used three types of pre-mixed composite powder to form the three intermediate layers between the bond

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