Abstract

Carbon nanotube (CNT) is well known for its strength and stiffness. It can be used as reinforcement in a plasma sprayed ceramic coating and improve its properties. However, CNT has a tendency to agglomerate. These agglomerates cause disturbance in powder flow during plasma spraying and exacerbate the properties of the coating. It is possible to disperse CNT in a ceramic powder using heterocoagulation, a colloidal processing technique. In this investigation three micro-size ceramic powders, namely, agglomerated alumina, crushed alumina and crushed titania, were doped with 1 or 2wt% CNT using three procedures, namely heterocoagulation, ball milling without crushing media and ball milling in the presence of ethanol. It has been observed using X-ray dot mapping that heterocoagulation produced a homogenous dispersion of CNT in the ceramic powder. The flowability of powders was quantified with the help of standard powder feeder. The heterocoagulated powders exhibited better flowability as compared to conventional powders. Next, these powders were plasma sprayed on bond coated steel substrate to produce coatings. The CNT retention and dispersion in the coatings were characterised using Raman spectroscopy and Raman imaging techniques, respectively. The Raman image revealed that the CNT was dispersed homogeneously in the coating produced from the heterocoagulated powder. During spraying, the molten ceramic spread over CNT elements or aligned bundles by capillary action and protected it from the hot plasma plume. Hence, CNT suffered only limited damage. All coatings had shown good microstructural integrity. The properties of the coatings produced from the heterocoagulated powders were superior to those of the coatings produced from the pristine powders. For example, the heterocoagulated crushed alumina coating demonstrated 29% decrease in porosity, 9% increase in hardness, 23% increase in indentation fracture toughness, and 20% increase in elastic modulus. Morphology of splats with and without CNT were compared. The CNT reinforced splats were bigger, disc shaped and were more resistant to scratching as compared to the unreinforced splats. The scratch adhesion strength of the full-grown coatings was measured using micro scratch tester equipped with a Rockwell C type conical indenter. The scratch adhesion strength of the CNT reinforced coatings was upto 176% higher than that of the conventional coatings. The wear performance of the heterocoagulated crushed alumina coatings was compared with the pristine crushed alumina coatings using a ball on disc tribometer. A 6mm WC-Co ball was used as a counter body. The wear rate was measured in terms of mass loss and wear coefficient. The wear resistance increased in the following order: coatings with no CNT, 1wt% CNT and 2wt% CNT. This is attributed to an increase in coating hardness, toughness and cohesive strength and a decrease in coating porosity in presence of CNT. Fatigue and microfracture were the predominant wear mechanisms.

Keywords: thermal spray; plasma spray; carbon nanotube; zeta potential; heterocoagulation; splat; scratch test; wear test