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ORIGINAL ARTICLE

Characterization of plasma-sprayed carbon nanotube (CNT) -reinforced alumina coatings on ASME-SA213-T11 boiler tube steel

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Abstract In this research work, carbon nanotube (CNT)-reinforced Al_2O_3 coatings were prepared and successfully deposited on ASME-SA213-T11 boiler tube steel. Coatings were deposited by the plasma spray process. Ni-Cr was also used as a bond coat before applying CNTs-Al_2O_3 coatings. The coatings were subjected to metallography, XRD, SEM/EDAX, and X-ray mapping analysis. The porosity of CNT-Al_2O_3 mixed coatings was decreasing with increase in CNT content. The CNTs were found to be uniformly distributed within the Al_2O_3 matrix. The CNTs were chemically stable during the spray forming. It did not react to form oxides or aluminum carbides even at the very high processing temperature.

Keywords Characterization · Thermal spray · Carbon nanotubes · Boiler steel · SEM · EDAX

1 Introduction

Hot corrosion is degradation of metals at high temperature and has become an important concern due to ever-increasing global competition [1, 2]. Advancements in the development of materials have led to increase in operating temperature of gas turbines, boilers, and industrial waste incinerators [3]. The use of low-grade fuels along with high temperature has accelerated the phenomenon of hot corrosion [4–6]. The problem of hot corrosion was taken for the first time in the 1940s as a serious problem with the degradation of boiler tubes in the steam-generating plants [7, 8]. A case study revealed that out of 89 failures of boiler tube in 1 year, 50 failures were due to hot corrosion by ash [9].

Plasma spraying is a commonly used manufacturing coating technique to change surface properties of metals and alloys. Plasma spray technique has the advantage of depositing metals, ceramics, and a combination of these and can generate homogenous coatings with desired microstructure on a wide range of substrate materials [10]. Plasma spraying is a well-established thermal spraying technique to apply coatings for improving corrosion resistance on boiler components [11–13]. Plasma-sprayed coatings of various ceramic materials such as alumina (Al_2O_3) and calcia (Ca)-stabilized zirconia (ZrO_2) have been developed for various high-temperature applications [10, 11, 14–17]. Alumina is an exceptionally important ceramic material with high hardness, chemical inertness, and high melting point and can retain up to 90% of its strength even at 1100 °C [18]. It is reported that the corrosion resistance of alumina coatings is higher than that of cermet and metallic coatings [19, 20]. Because of the spraying process, the thermal sprayed coatings contain cracks or voids at splat boundaries, and these coatings are attacked through these voids [21–23]. Therefore, researchers are still interested in developing new coating materials for enhanced corrosion resistance at high temperature [24].

A new era of interest in the field of nanotechnology began with the invention of carbon nanotubes (CNTs) in 1991 [25–27]. CNTs are 100 times stronger than the high-grade carbon steels and have exceptional thermal and electrical properties [28–32]. These properties of CNTs make them potential reinforcement for the composite materials and many authors have used CNTs as reinforcements for composite materials [24, 33–35]. Guo et al. [36] have deposited CNTs on the micropunches of WC/Co, which successfully increased the

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