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Improving hot corrosion resistance of Cr_3C_2–20NiCr coatings with CNT reinforcements

Khushdeep Goyal[a] and Rakesh Goyal[b]

[a]Department of Mechanical Engineering, Punjabi University, Patiala, India; [b]Chitkara University Institute of Engineering and Technology, Chitkara University, Punjab, India

ABSTRACT
Carbon Nanotubes (CNT) reinforced Cr_3C_2–20NiCr composite coatings were prepared and deposited on alloy steel using high-velocity oxyfuel (HVOF) thermal spraying method. The comparative effects of variation in CNT content (from 1 to 2 weight percentage) on mechanical properties and hot corrosion behaviour in super-heater zone of actual coal-fired boiler of a thermal power plant at 900°C have been investigated. After exposure to boiler environment, the corrosion products have been analysed by thermogravimetric analysis, X-ray diffraction, scanning electron microscopy, energy dispersive and cross-sectional analysis techniques. The results confirmed that variation in CNT content improved the mechanical and microstructural properties of surface coatings by modifying their surface characteristics. The variation in CNT content improved the corrosion protection property of composite coating at high temperature of exposure. Reduction in corrosion rate was observed with increase in CNT content from 1 to 2 weight percentage in the Cr_3C_2–20NiCr coating matrix.

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Introduction

Hot corrosion of metals and their alloys has been identified as a serious issue in high-temperature boiler environments where coal and biomass are used as fuels [1,2]. In the coal-fired boiler, oxidation and sulphidation become a major problem due to presence of oxygen and sulphur. The burning of fuels with significant amounts of sodium, vanadium, and potassium results in formation of highly corrosive vanadates of sodium and potassium [3,4]. T22 ferritic steel has been widely used in the boilers in Indian thermal power plants, and it suffers from severe oxidation attack in high-temperature environment due to vanadates of sodium and potassium penetrating deep into the substrate. The poor corrosion resistance of bare T22 steel is due to formation of porous and loosely bound Fe_2O_3 rich scale [5]. Na, and S reacts with oxygen to form sulphates of sodium, which again reacts with vanadium to form complex vanadates of sodium, and these complex vanadates are called ash [6]. These complex compounds get deposited on the surface of boiler steel to initiate corrosion.

Thermal spray coating technique is an important technique to provide significant protection to bare steels in high-temperature boiler environments [7,8]. For effective applications at high temperature, these coatings should have sufficient thickness, low porosity with good surface finish, high hardness than substrate material. Ceramic materials are the ideal materials for these coatings due to high thermal stability, high hardness and low thermal conductivity [1,9,10]. Several studies have shown Cr_3C_2–NiCr coatings have high corrosion and erosion resistance at high temperatures upto 900°C. It is reported that corrosion resistance is provided by NiCr matrix, whereas erosion resistance is attributed to the formation of carbide ceramic phase. The coefficient of thermal expansion of Cr_3C_2 is almost similar to that of nickel and iron, which helps to minimize the stress generation during thermal cycling in actual boiler environments. The thermal sprayed coatings are porous due to high value of porosities, and hence have many local micro-cracks or through pores, [11–13]. The corrosive fluids attack the substrate steels through these cracks [14–16]. The mechanical properties of these coatings downgrade due to high value of porosity, which in turn affects the corrosion resistance of these coatings. Researchers have used composite materials to improve the mechanical and microstructural properties of thermal spray coatings by using high hardness reinforcements [17–21]. In recent past, carbon nanotubes (CNT) are emerged as excellent reinforcement materials for composites due to their excellent mechanical properties including strength, modulus, stiffness which exceeds properties of all current materials [22–24]. Keshri et al. [25] reported that increase in wear resistance of composite coatings reinforced with CNT was attributed to the higher hardness of CNT composite coating and also due to CNT bridging between splats. Balani et al. [26] investigated wear behaviour of CNT

CONTACT Khushdeep Goyal khushgoyal@yahoo.com Department of Mechanical Engineering, Punjabi University, Patiala 147002, India