Improving the high-temperature oxidation resistance of ASME-SA213-T11 boiler tube steel by plasma spraying with CNT-reinforced alumina coatings

Rakesh Goyal
Department of Mechanical Engineering, IKG Punjab Technical University, Kapurthala, India and
Department of Mechanical Engineering, Chitkara University, Rajpura, Punjab
Buta Singh Sidhu
Department of Mechanical Engineering, M.R.S. Punjab Technical University, Bathinda, India, and
Vikas Chawla
Department of Mechanical Engineering, IKG Punjab Technical University, Kapurthala, India

Abstract

Purpose – This paper aims to discuss that a conventional Al_2O_3, 1.5 Wt.% carbon nanotubes (CNTs)-Al_2O_3, 2 Wt.% CNTs-Al_2O_3 and 4 Wt.% CNTs-Al_2O_3 composite coatings were deposited with the help of Plasma spray process.

Design/methodology/approach – To better understand the effect of CNT reinforcement on oxidation resistance, high-temperature oxidation behaviour of conventional Al_2O_3, 1.5 Wt.% CNTs-Al_2O_3, 2 Wt.% CNTs-Al_2O_3 and 4 Wt.% CNTs-Al_2O_3 composite coatings at 900°C was compared with the performance of the uncoated ASME-SA213-T11 boiler tube steel substrate.

Findings – The results showed that the CNT-reinforced alumina coatings exhibited better oxidation resistance and thermal stability than uncoated ASME-SA213-T11 boiler tube steel. The coated steel substrates had a lower mass gain rate than the substrate after different oxidation times.

Originality/value – Limited literature is available where the CNT have been reinforced into the composite alloy powders and has been thermally spray-deposited for various surface engineering applications. This research showed that with the increase in the percentage of CNTs into the alloy powder mixture, there is a significant reduction in weight gain and hence higher resistance to oxidation.

Keywords Corrosion, Coatings and linings, Composites, Degradation, Microscopy, High temperature

Paper type Research paper

1. Introduction

At high temperatures, metals and alloys get oxidized when they are heated in air (Sidhu *et al.*, 2006; Lawrence and Li, 2003). Owing to oxidation reaction, sometimes, a protective oxide scale is formed which resists corrosion attack (Singh *et al.*, 2005). Therefore, oxidation is an important high-temperature corrosion phenomenon. The rate of oxidation increases with a further increase in temperature (Singh *et al.*, 2015; Jones, 1983; Eliaz *et al.*, 2002; López *et al.*, 2014).

Boiler tubes are used in a high-temperature environment such as in thermal power plants and industrial waste incinerators (Sabau and Wright, 2010). The tube material is subjected to high thermal stresses and high-temperature oxidation environment. These are also attacked chemically by oxidation and high-temperature corrosion (Zhang *et al.*, 2016). The boiler tube steels are not able to resist high-temperature oxidation/corrosion behaviour; therefore, protective coatings on the boiler tubes are used to counter the oxidation/corrosion. So, it is important to study the oxidation behaviour of high-temperature coatings.

Plasma spraying is an important thermal spraying technique to apply coatings on boiler tube steels (Zhang *et al.*, 2016; Katiki *et al.*, 2014; Erickson *et al.*, 1998; Schulz *et al.*, 2003). With this technique, metals, ceramics and a combination of metals and ceramics can be homogenously deposited on a wide range of substrate materials (Sidhu *et al.*, 2005). These techniques have been successfully used to develop coatings of various ceramic materials such as alumina (Al_2O_3), calcia (Ca)-stabilized zirconia (ZrO_2) for various high-temperature applications (Katiki *et al.*, 2014; Sidhu *et al.*, 2005; Karthikeyan *et al.*, 1988; Khan and Lu, 2007; Sidhu and Prakash, 2006; Du *et al.*, 2010; Singh *et al.*, 2006). Alumina has high hardness, chemical inertness with high melting point and can retain its strength even at 1,100°C (Hegazy *et al.*, 2009). Alumina coatings have higher corrosion resistance than metallic and cermet coatings (Celik *et al.*, 2005; Malatji *et al.*, 2015). One

The current issue and full text archive of this journal is available on Emerald Insight at: **www.emeraldinsight.com/0003-5599.htm**

Anti-Corrosion Methods and Materials
 [ISSN 0003-5599]
[DOI 10.1108/ACMM-03-2017-1778]

Received 25 March 2017
Accepted 17 November 2017