Chapter 5
Application of Thermal Spraying Techniques Used for the Surface Protection of Boiler Tubes in Power Plants: Thermal Spraying to Combat Hot Corrosion

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ABSTRACT

Distinct methods of depositing the coatings are available according to the intended area of application with a sole objective to protect the surface of structural component like boiler, boiler tubes, and heat exchangers from any mechanical or chemical damage. The main benefit is to minimize the manufacturing cost of a new component and also its fabrication. Thermal spraying is the commonly used technique to tailor the surface properties with a cost-effective approach. The different techniques of thermal spraying such as plasma, HVOF, cold spraying, etc. were investigated and introduced. Although each of these processes has advantages, there are also certain disadvantages associated with them, which limit their application. In the chapter, different methods of depositing coating by thermal spray are discussed and compared. By developing advanced techniques and new coating materials, the life and efficiency of power plants can be enhanced in the future.

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1. INTRODUCTION

Materials are lifeline or backbone of the modern industry and nothing exist without them (Prashar & Vasudev, 2020). Hot corrosion or high temperature corrosion of boiler tubes is the serious problem faced by the power plant industry (Beltran & Shores, 1972). According to a survey annual loss due to all types of corrosion is US$ 6500 million (Kumar et al., 2018). Corrosion mainly occurs due to aggressive gases such as HCl, H_2O, etc in combination with the metal and alkali chlorides that are generated during combustion process. Low grade fuel used in boilers contains sulphur and during combustion produces SO_2 which get oxidized to SO_3. This SO_3 by further reacting with sodium chloride (NaCl) and water vapor forms Na_2SO_4 having melting point 884°C and get condensed onto the boiler tubes together with fly ash (Natesan, 1976). Vanadium in small quantities is also present in coal and during combustion forms V_2O_5 having melting point 670°C. This V_2O_5 further reacts with Na_2SO_4 and forms sodium vanadate. This sodium vanadate is extremely corrosive in nature to the materials that operates at high temperatures (Hwang & Rapp, 1989; Khanna & Jha, 1998). According to (Shih et al., 1989) when surface of a metal or alloy got covered with liquefied salt (Na_2SO_4) at high temperatures, then oxidation occur at higher rates. This accelerated form of oxidation is termed as hot corrosion. Hot corrosion is also shown to be caused by sulfates, vanadates and carbonates (Pettit, 2011).

The reactions taking place at high temperatures for formation of sulphates, vanadates, and carbonates are as following:

SO_3 reacts with sodium chloride (NaCl) and water vapour to form Na_2SO_4; equation (1)

$$2(Na, K)\,Cl + SO_2 + ½\,O_2 + H_2O = (Na, K)_2\,SO_4 + 2HCl \quad [1]$$

When temperature is approximately around 600°C, compounds of sodium sulfate and vanadium pentoxide are formed, which have more corrosive properties. This vanadium pentoxide further reacts with sodium sulfate and forms sodium vanadate which is extremely corrosive ; equation (2)

$$Na_2SO_4 + V_2O_5 = 2NaVO_3 + SO_3 \quad [2]$$

Corrosion results from two main impurities: carbon dioxide and oxygen. Carbonates and bicarbonates in fresh water are the major source of carbon dioxide contamination. Natural water contains sodium, calcium and magnesium bicarbonate. When these minerals enter into the boiler, heat causes them to break down as follow: equation (3)

$$Ca(HCO_3)_2 + Heat = CaCO_3 + H_2O + CO_2 \quad [3]$$

Calcium bicarbonate calcium carbonate sludge

One alternate is to protect the boiler tubes with a suitable coating material and is considered to be a preferred approach (Eliaz et al., 2002). High temperature performance of the coatings not only relies on coating composition but also depend upon the deposition process used and its parameters. Thermal spraying is the commonly used method to tailor the surface properties with a cost effective approach. In addition to this thermal spray is capable of depositing any type of coating powder (ceramics, polymer, composite and metallic) onto any kind of substrate material (Davis, 2004; Gil & Staia, 1999, 2002; Pawlowski, 2008; Singh & Prakash, 2009). Thermal spraying is considered to be one of the most adaptable