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Review Paper

A comprehensive review of the corrosion and erosion resistant coating on the fire side in power plant boilers

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1. ABSTRACT

Conventional steels and their alloys are not able to withstand high temperature corrosion in thermal power plant boilers. For boiler fireside components, issues of concern include erosion and corrosion in operating environments. Different thermal spray coating techniques have been developed to spray different types of coatings on boiler steels. Advances in thermal spraying techniques have led to the development of coatings with corrosion resistance properties. In this article, firstly, the introduction and the necessity of applying the coating used for boiler equipment is stated, then the studies carried out until today about the performance, developments and applications of thermal spray coatings for resistance to high temperature corrosion were examined, and finally a case study of using this coating in a power plant was mentioned. Among the types of coatings, Ni-20Cr alloy and their composite with carbide compounds is the most optimal coating with good performance in all types of boilers.

Keywords: Corrosion, Erosion, Boiler, Coating.

2. INTRODUCTION

Materials such as steels are exposed to various types of working conditions at high temperatures. This use of steels at high temperature leads to corrosion problems. Hot corrosion is an accelerated corrosion caused by the presence of salt contaminants such as Na_2SO_4, NaCl, and V_2O_5 that combine and form molten deposits that destroy the protective surface oxides. Hot corrosion can occur by two mechanisms called type I and type II hot corrosion, which are also known as high temperature hot corrosion (HTHC) and low temperature hot corrosion (LTHC), respectively. HTHC type I is observed in the temperature range of about 825-950 °C (the melting point of pure Na_2SO_4 is 884 °C). This type of state is characterized by the formation of sulfides and the corresponding reduction of the reactive component in the alloy bed. In coal-fired power plants, fire side corrosion includes type II hot corrosion. Na_2SO_4 or K_2SO_4, formed from the reaction of SO_2 with NaCl or KCl (found in coal), is the main salt precipitate in ash. Since the maximum outer wall temperature of steam generation tubes ranges from 550°C to 650°C, hot corrosion does not occur until the sulfate deposits react with SO_3 to form pyrosulfates [1].

$$K_2SO_4 + SO_3 = K_2S_2O_7 \quad (1)$$

The amount of SO_3 is about 150 ppm, and for the reaction with Na_2SO_4, the need for SO_3 is about 2500 ppm. When pyrosulfates are formed, a complex mixture of these two melts is created at around 451°C for potassium salt and 551°C for sodium salt, and severe hot corrosion occurs. Fuel oil and residual coal are widely used throughout energy production systems due to the lack of high-quality fuels and financial reasons. These fuels include impurities that create compounds on the surface of materials at a low melting point and cause corrosion. Such compounds are usually known as ash. The said ash deposites on the surface of the material and causes corrosion. Material degradation occurs when these molten compounds dissolve the protective oxide layers that naturally form on the material during boiler/gas turbine operation. Failure to avoid or at least recognize hot corrosion in its early stages has led to many accidents that have resulted in loss of life and deterioration of materials. In addition to the direct costs of outages and loss of productivity, tens of billions of

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dollars are typically spent to repair corroded structures, machinery, and equipment, and sudden material degradation can lead to to human incapacity or even life-threatening

3. Effecs of the coatings used in the boiler equipment

The reasons for the failure of many elements of active installations in the power plant industry are the combined processes of erosion and corrosion that occur at high temperatures. These processes are most intense in the combustion chamber, on the surfaces of superheaters and economizers, as well as in fuel and air feeding systems and ash removal. A diagram showing the elements of the boiler installation that are subject to the most severe erosive-corrosive wear is shown in Figure 1.

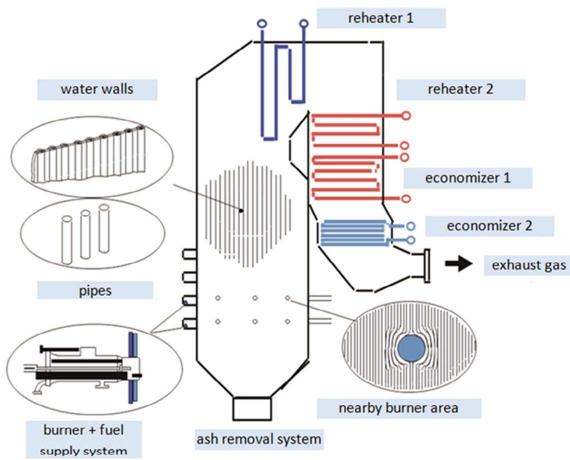

Figure 1. The damaged parts of the boiler against wear and corrosion [2].

The actual operating conditions in boilers are:
1- Wear of abrasive particles caused by the collision of hard ash particles at different angles
2- High operating temperature (on metal elements, it is about 550 °C)
3- Corrosive performance of fuel combustion products
This promotes the use of a coating characterized by high hardness and good adhesion, and makes it possible to obtain an optimal thickness, low porosity and a complex phase composition, which has a high corrosion resistance against sulfur-containing compounds. It guarantees chlorine and water vapor by reducing oxygen. Among the many methods of creating a protective coating, only thermal spraying allows the production of coatings with the above characteristics. The great advantage of thermal spraying compared to conventional methods such as pad welding is the high speed and mobility of the process, which allows the production and repair of coatings directly in boilers even during short downtimes. Thermal spraying methods do not have significant material limitations in relation to the coating and base composition and allow the production of coatings with high hardness and a thickness of several millimeters. Among the thermal spraying methods, flame, arc, plasma and HVOF methods are used in practice to protect boiler elements. Flame and plasma methods are rarely used due to the complexity of the process or relatively high costs.
To summarize this section, Ni-20Cr alloy compositions require a long initiation time in which the hot corrosion process progresses from the initiation stage to the propagation stage. Table 1 shows a summary of research conducted by various researchers on Ni-Cr coatings for high temperature applications using thermal spray processes.

Table.1. Summary of the investigations on Ni-Cr coatings using thermal spray process

Coating Material	Substrate	Thermal Spray Process	Testing Environment	Important Findings	Reference
NiCrAlY, Ni-20Cr, Ni_3Al and Stellite-6	Fe-based Super alloy (32Ni-21Cr-0.3Al-0.3Ti-1.5Mn-1.0Si-0.1C-Bal Fe)	Plasma sprayed	Na_2SO_4-60%V_2O_5 under laboratory condidions	Resistance to hot corrosion fol lows the trend NiCrAlY coating >Ni-20Cr coating >Ni_3Al coat ing >Stellite-6 coating	[3]

Ni-20Cr	A213 347H	HVOF	Actual boiler at 700◦C	Coatings enhanced the oxidation resistance of the steel by 85%.	[4]
Ni-Cr (Ni-45Cr-4Ti) and FeCrAl coatings	-	HVAS sprayed	Power plant boilers	Ni-Cr coatings had slightly lower pores than FeCrAl coatings	[5]

4. CONCLUSION

Hot corrosion is a serious problem in high temperature applications for various boiler components of power plants. The severity of this problem increases when low-grade fuel is used in the boilers of the power plant, because of the unavailability of high-grade fuel and the associated costs of procurement, low-grade fuel is used. The only solution to increase the life of boiler tubes is to use thermal spray coatings to deal with the problem of hot corrosion. Thermal spraying technologies allow the production of complex coatings on various metal surfaces using different special coating materials. These coatings are characterized by a set of superior properties, which include: 1) high corrosion resistance, also at high temperatures, 2) high erosion resistance, and 3) the possibility of repairing the coatings at the place of use. These features enable their widespread use in the protection of boiler elements. The results of the review article showed that Ni-20Cr coatings and their composites can be successfully deposited on boiler steels using different thermal spray processes. In addition, nickel alloyed with chromium (Ni-20Cr) oxidizes to Cr_2O_3 and other protective spinel phases such as $NiCr_2O_4$, which makes it suitable for use up to 950°C to combat hot corrosion in various environments. As a result of the deposition, corrosion and erosion processes that can occur under these operating conditions, these issues must be thoroughly investigated for critical components (such as heat exchangers, gas cleaning systems and gas turbines) to identify potentially life-limiting conditions. A thorough knowledge of these processes and the responses of current material systems facilitates material selection and maintenance scheduling, reduces the risk of unexpected component failure, and identifies conditions that require the development of new materials or coating systems.

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