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High temperature corrosion behaviour of superalloys under actual waste incinerator environment

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ABSTRACT

In the present study, three superalloys viz. Superni 718, Superni 600 and Superco 605 were hung inside the secondary chamber of actual medical waste incinerator where the temperature is more than 1050 °C. Burning of medical waste produces very corrosive environment at high temperature which can degrade the components of construction. Hence the three superalloys were kept for 1000 h inside the chamber. Corrosion rate has been calculated in mpy. Corrosion products so produced were characterized using SEM/EDS and XRD technique. It was observed that both the Nickel based superalloys showed better corrosion resistance than the cobalt based superalloy under the given environment.

1. Introduction

The treatment of municipal and hazardous waste is done most effectively in incinerators. This avoids uncontrolled chemical reactions in the landfill which can lead to pollution of the environment. Waste incinerators are extensively used because of their property of disposal of waste under controlled inertization and ability to reduce the volume of the waste by 90%. The heat released during combustion can further be used for the production of electricity [1]. "During the combustion of waste, the materials of construction suffer from corrosion damage. High temperature corrosion that occurs during waste combustion in a furnace or in a boiler comprises of rapid scaling by sulphides, scale delamination, oxide scale fluxing due to the presence of molten salt species, internal oxidation because of the penetration of sulphur species along the grain boundaries, fouling caused due to heavy deposits influencing heat and mass transfer, erosion or impaction effects. There are distinctive modes of corrosion attack in waste incinerators which can cause material deprivation. Corrosion damage occurs due to the presence of vanadium in fuel containing residual oil and damage due to the aggressive species attack [2]. The materials which are used to construct the components exposed directly to high temperature such as boiler linings which suffer metal loss. This may be due to the fluxing of the oxide scale which provides protection to the metal. The fluxing occur due to the presence of salt ash deposits which leads to the rapid scaling of the oxide and scale flaking which further enhances inter-granular corrosion [3].

The ash particles and the flue gases present inside the furnace can lead to a catastrophic corrosion due to the chemical attack. The boiler components which are most susceptible to corrosion are the incineration chamber, the water walls of the first blank (empty) passes and the super heaters [4] Incineration techniques are extensively used to discard various types of waste such

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as medical waste, industrial and municipal solid waste which required very high temperature [5]. Incinerators are generally operated at very high temperature which lies between 500 °C to 1100 °C depending upon the type of waste to be burnt, the volume of the waste and the auxiliary fuel used to burn the waste [6]. Medical waste discarded in the incinerators generally consists of waste from operating room and laboratories [4]. This waste is highly contaminated as it contains infectious needles and syringes which can spread diseases such as hepatitis C if reused again [6]. Incinerators are generally operated at very high temperature to destroy any kind of microorganism present in the waste. Burning of contaminated waste produces corrosive salt species in the form of fly ash. The corrosive salt species combined with high temperature create very aggressive environment for construction material thereby decreasing the service life of components facing higher temperature. Ni et al. [7] investigated the composition of the fly ash in the medical waste incinerator operated in China. They found the presence of salt species containing calcium, aluminium, silicon, magnesium, sodium, oxygen, carbon, chlorine and sulphur in the fly ash. They also compared the level of chlorine present in municipal solid waste incinerator and medical waste incinerator and reported existence of higher chlorine concentration in the case of medical waste incinerator. Weulersse et al. [8] also found that waste incinerator suffered from higher degradation as compared to coal fired boilers. This is because of the formation of thick and adherent corrosive layer of salt species which leads to the corrosion in the form of internal oxidation followed by active oxidation due to the presence of chlorides. Therefore, an attempt has been made to evaluate the hot corrosion performance of Superni 600, Superni 718 and Superco 605 superalloys in an actual medical waste incinerator environment. The samples were hung inside a medical waste incinerator at Base Hospital, Kashmir, India. Dual chamber or pyrolysis incinerator is being used for burning medical waste. In primary chamber the medical waste is burnt at 850 °C and the resulting flue gases get transferred to a secondary chamber where they get burnt at 1050–1100 °C. The samples were hung in the inlet of secondary chamber where the temperature is 1050–1100 °C. The studies have been reported for 1000 h exposure.

2. Experimental

2.1. Composition of substrate

The composition of the samples was determined using spark spectroscopy. The Ni-based superalloys namely, Midhani grade Superni 718 and Superni 600, and Co-based superalloy namely Superco 605 have been selected as the substrate materials for the present study. The composition of the substrates is given in Table.1.

2.2. Sample preparation

The specimens of size 20 × 15 × 5(mm) have been cut from the sheet and were polished using 220, 320, 400, 600 and 800 grit size emery paper followed by cloth polishing using alumina powder of 0.3 μm.

2.3. Corrosion studies in actual incinerator environment

Prepared samples were hanged inside the secondary chamber of Thermax medical waste incinerator at Base Hospital, Srinagar, Kashmir, India. The temperature inside the primary chamber was in the range of 850–900 °C and secondary chamber 1050–1100 °C. The capacity of the plant is around 65 kg/h. About 20 l of diesel is used every hour for the combustion of the waste. The position of the samples in actual medical waste incinerator (Fig. 1(a)) is shown in Fig. 1(b). The Kanthal wire 'A' grade was used to hung the specimens inside the chamber around the thermocouple. Cyclic study was carried for 1000 h. Each cycle consists of 100 h followed by 1 h cooling in ambient air. At the end of each cycle the samples were analysed visually. The corrosion products so formed on the surface of specimens were analysed using SEM/EDS and XRD characterization techniques. SEM has been done to analyse the surface morphology along with EDS which provides the elemental distribution. XRD technique has been used to determine the phases formed on the surface of the specimen.

2.4. Thickness loss measurements

The thickness loss is a means to express the penetration rate due to corrosion of the metal specimen. Perhaps the most common unit of corrosion penetration recognized in the United States is milli-inches per year (mpy). The formula utilized to convert

Table 1
Composition of superalloys.

Name of superalloys	Elements, wt.%												
	Fe	Ni	Mn	Cr	Cu	W	Mo	Co	Si	Ti	C	Nb	Al
Superni 600	10.max	Bal.	0.05	15.5					0.3		.021		
Superco 605	3.0	10.0	1.5	20.0		15.0		Bal.	0.3		0.08		
Superni 718	18.5	Bal.	0.18	19.0	0.15		3.05		0.18	0.9	0.04	5.13	0.5