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Failure of Alloy 20 nozzles used for spraying sulfuric acid in an incineration furnace

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ABSTRACT

Alloy 20 nozzles, which were used for spraying sulfuric acid into an incineration furnace of a petrochemical plant, failed prematurely after 7 days of service at approximately 1453 K. The material for manufacturing the nozzles complied with Alloy 20 (ASTM B473 UNS N08020) specification. Investigation by optical microscopy, scanning electron microscopy and metallographic analysis showed that the nozzles failed by erosion corrosion action of concentrated sulfuric acid. Five-step mechanisms of erosion corrosion damage were proposed. Using SiC or Si_3N_4 as materials for coating or fabricating the nozzle part could potentially alleviate erosion corrosion problem.

1. Introduction

The waste incinerators for energy generation have been widely recognized as the way to reduce fossil fuels consumption and preserve the environment by decreasing disposal of waste into the ground. Nonetheless, the corrosion problems associated with chlorine-laden waste have significantly reduced the efficiency of these plants through service downtime. Investigation of Ni-based superalloys in corrosive incinerator environment at 1173 K showed that these superalloy materials, namely, N06075, N07718 and N06601, are suitable for boiler tubes in highly corrosive waste incinerator and other similar environments, especially, when compared to boiler steel grade A1, T11 and T22. These superalloy materials are able to prolong the service life of components by increasing the reliability of the boiler operations [1].

Other studies include the failure of Hastelloy C-276 quench nozzles installed in the firebox of an incinerator in the ethylene dichloride unit of a petrochemical plant [2] and the severe degradation of Type 310H stainless steel bed nozzles installed in a fluidized bed power boiler [3]. For Hastelloy C-276 quench nozzles, the study indicated that corrosion of such nozzles most likely resulted from hydrochloric acid (HCl) formed at about 1333 K following the failure of the refractory lining. Upgrading the construction material to Alloy C-59 or applying SiC coating was recommended [2]. For Type 310H (UNS S31009) stainless steel bed nozzles, they failed in operating environment (750 K steam at 6.52 MPa) in less than 12 months of operation. Field tests confirmed that replacement with Alloy 625 would extend service life of bed nozzles at least twice as long as those fabricated from Type 310H stainless steel [3]. Alloy 20 (N08020) is also one of the materials recommended for construction of tanks and pipes for handling and storing concentrated sulfuric acid [4].

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In the current work, a petrochemical plant has experienced premature failure of the nozzles used for feeding concentrated sulfuric acid into an incineration furnace, where process wastes are decomposed through reaction with acid at high temperature. The service condition of nozzle and a schematic drawing of the incineration furnace are shown in Fig. 1. During service, the temperature inside the furnace, which was monitored by an infrared pyrometer, was maintained at about 1453 K. Concentrated sulfuric acid (98.5%) was transported into the incineration furnace through a tube at pressure up to 350 kPa above ambient. The liquid inside the tube and the nozzle was maintained at temperature of 313–323 K and was immediately fed into a mixing chamber inside the nozzle set. In the mixing chamber, the two-phase mixing between liquid sulfuric acid and air at high speed caused atomization of liquid sulfuric acid into droplets [5] with mean size finer than 25 μm, which left the nozzle tip into the incineration furnace.

Alloy 20, which is known for its exceptional resistance to sulfuric acid, was selected as the material for fabrication of nozzles. Nonetheless, the nozzles severely degraded and required new replacement every 7 days. It is apparent that even with optimum material with respect to the resistance to sulfuric acid, the service life of the nozzles remains unacceptable, leading to high cost from downtime, maintenance and materials replacement. Consequently, the root causes of rapid deterioration of the nozzles were investigated by means of optical microscopy, SEM and metallographic analysis. The mechanism of the rapid degradation of the nozzle in such service conditions could be proposed.

2. Experimental method

On-site investigation was conducted to observe the service condition, investigate the failed nozzle and furnace, and to collect the samples including the failed parts as well as the un-used parts for laboratory testing. After the samples were taken to the laboratory, bulk compositions of the failed nozzle were analyzed using an optical emission spectrometer and compared with ASTM B473 UNS N08020 specification. The failed nozzle was then thoroughly examined visually by a stereo microscope to study the pattern of damage. High magnification observation of the damaged surface was conducted using a scanning electron microscope (SEM). For metallographic analysis, the samples were longitudinally sectioned through the damaged areas and prepared by the following steps: cold mounting in resin, grinding with silicon carbide paper, polishing with diamond suspension, and etching in glyceregia solution (one part of HNO_3, three parts of HCl and 2 parts of glycerol). Metallographic examination was then carried out under a reflected light microscope.

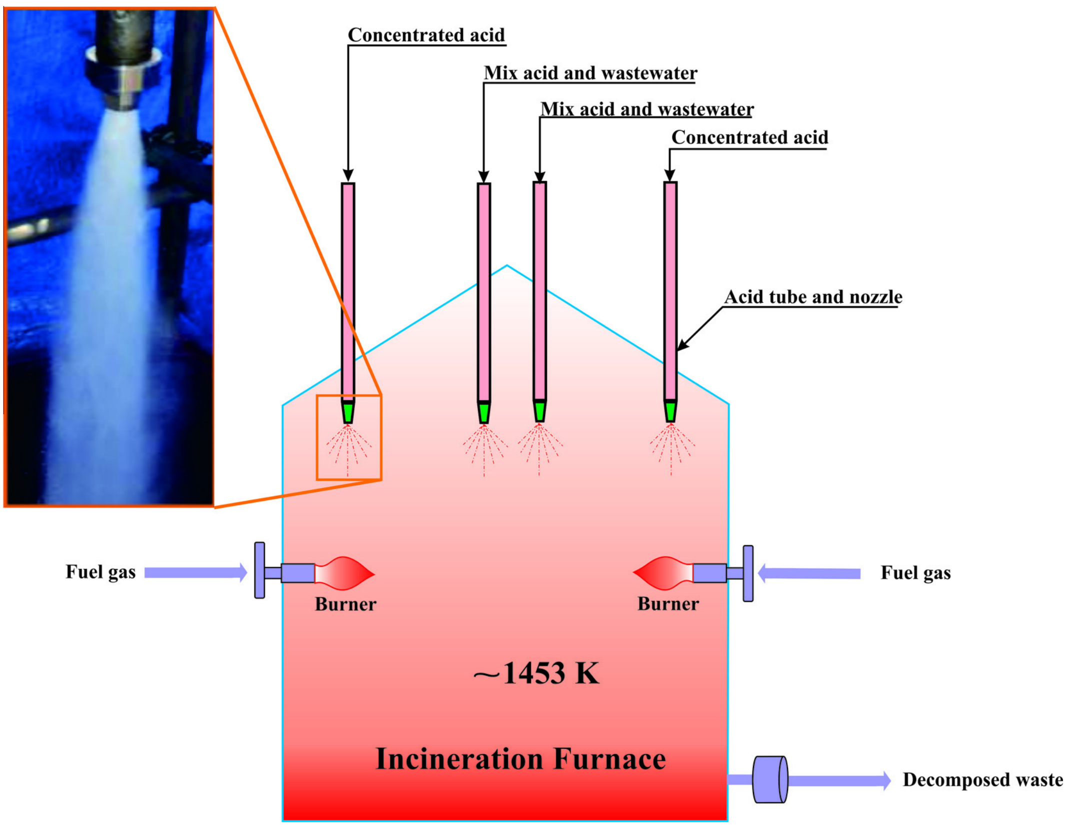

Fig. 1. The service condition for spraying the sulfuric acid into the incineration furnace.