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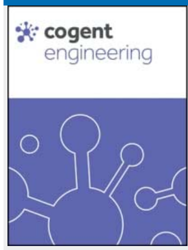

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Effect of cyclic high temperature fluctuations on the corrosion failure of S40900, S43036, S31635 and S44400 stainless steels

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Corrosion resistance of untreated S40900, S43036, S44400 and S31635 stainless steels (S409, S430, S444 and S316) in 0.05 M H_2SO_4/3.5% NaCl solution was investigated and compared to their heat-treated counterparts after cyclic temperature variation between 1000°C and 37°C by potentiodynamic polarization, potentiostatic analysis, open circuit potential measurement and optical microscopy. Results showed untreated S409 exhibited the weakest resistance to corrosion at 8.406 mm/y while untreated S316 displayed the highest resistance at 1.581 mm/y. Cyclic heat treatment caused significant increase in corrosion rate of untreated S409, S430 and S444 by 21.92%, 38.46% and 94.76%. Corrosion rate of untreated S316 decreased by 69% to 0.490 mm/y. Untreated and heat-treated S316 exhibited the least metastable pitting tendency while heat-treated S409 and S430 exhibited the highest. Untreated S444 showed the highest tendency to passivate compared to heat-treated S409 and S430 with the lowest tendency. Heat treatment generally improved passivation rate, but not passivation resilience. Untreated S444 and heat-treated S430 exhibited the widest passivation range. Heat treatment increased the tendency for pit formation on the steels. Plots from open circuit potential measurement showed untreated S444 exhibited the lowest thermodynamic tendency to corrode with potential culminating at −0.201 V while among the heat-treated steels, S316 displayed the lowest corrosion tendency peaking at −0.288 V. Corrosion pits on heat-treated S409 were significantly larger compared to the untreated steel. Superficial corrosion pits visible on untreated S430 disappeared after heat treatment. Heat treatment decreased the occurrence of corrosion pits on S316 while miniature corrosion pits were present on heat-treated S444.

KEYWORDS:

corrosionsteelH_2SO_4passivationpitting

1. Introduction

Automotive exhaust systems consist of piping connections that control the movement of heated reactive gases from the ignition chamber of a vehicular engine to the exhaust manifold and through the exhaust silencer to the pipe outlet (Ikpe & Abdulsamad, 2017). Failure due to corrosion of the exhaust system causes rupture; resulting in leakages within the internal components, noise issues due to acoustic changes and environmental pollution. The high temperature conditions of exhaust systems coupled with the presence of dissolved corrosive anions necessitate cautious material choice in the production of exhaust system components for optimum and long lasting performance. The exhaust muffler is a component of an automobile exhaust system whose major functionality is to reduce the rumble passed out by the exhaust gases of an internal ignition chamber. It has an exterior shell, inner plates, inner pipes, end plates and other components. The temperature of exhaust mufflers is around 300°C to 500°C, but it can also handle higher temperatures up to 1200°C. Stainless steels are utilized in the production of automobile exhaust silencers due to their resilience to corrosion, high temperature stability and exquisite quality. Corrosion is the major factor responsible for the limited lifespan of automobile silencers and other parts of the automotive exhaust system (Hoffmann & Gümpel, 2009). Corrosion reactions control the chemical characteristics of the steel and greatly alter their physical and mechanical attributes.

Functional and structural damage of exhaust mufflers leads to loss of operating performance. Deterioration occurs due to corrosive precipitates within the silencer, de-icing agents utilized on icy roads, material sensitization at temperatures up to 600ºC, static loading due to low cycle and high cycle fatigue, corrosivity of coastal environments and the aggravating effect of acid deposition (Piepho, 1991). Automobile exhaust systems can be classified into two zones, i.e. the hot end and the cold end. At the cold end, condensations of released combustion gases (CO_2, H_2O, O_2, CO, HC, NOx and SO_2, etc.) continually accumulate, producing sulphuric acid and low levels of HCl acid. The condensates, coupled with the presence of Cl^- anion, produce a wet corrosive environment within the muffler leading to localized corrosion deterioration such as pitting (Heck & Farrauto, 2001; Nazir et al., 2016; Nockert et al., 2012). Resistance of stainless steel grades to pitting corrosion is heavily dependent on their alloy composition (Engstrom et al., 1999). Oxidation and spalling of the surface oxide layer dominate the corrosion reaction mechanism at the hot end of the exhaust system. As a result, stainless steel properties required for application therein must have high-temperature strength, thermal fatigue behaviour, vulnerability to oxidation and resistance to chloride corrosion. Thermodynamic and kinetic factors control the spontaneity and frequency of exhaust muffler corrosion in the form of general and localized deterioration of the surface (Shi et al., 2013).

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