Corrosion mechanisms and models for flue gas corrosion in aluminum heat exchangers

W. Wang, W. Schmid’, W. Förbeth
e-mail: wang@dechema.de
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Background

Condensing boilers are highly efficient heating boilers on the market, which achieve this high level of efficiency by using the waste heat in the flue gases to pre-heat the cold water entering the boiler.

Heat exchangers and drain systems in condensing boilers are contaminated and/or clogged with corrosion products because the formation of acidic condensate.

In order to improve the operational performance of the heat exchanger and to be able to reach the target of a maintenance free system, reliable design rules and operating philosophies are needed for these kinds of systems. For this purpose a better understanding of the underlying processes leading to corrosion and contamination/clogging of systems should be obtained.

Introduction

In the light of recent works, major factors which affect acid dewpoint corrosion should be: temperature gradient, water vapour content, concentration of sulphuric acid, operation periods, corrosion product formation, metal composition, cleaning procedures and HCl. With the aim of simply investigating the corrosion of heat exchangers in sulphuric acid of various strengths at various temperatures, an immersion test of aluminium alloys for heat exchangers has been conducted.

Experimental

Sample preparation:
The Aluminum heat exchanger (Aluminum 230 alloy, pressure die casting) has been cut into small samples with same size.

Test conditions:
The corrosion conditions are divided into two different categories depending on condensing operation of boiler, mild condition and harsh condition.

Mild condition is characterized as low temperature and concentration, which has same conditions as the end of heat exchanger. Harsh condition is designed with same high temperature and high acid concentration as the beginning of heat exchanger which is close to flue gas.

Results

Each sample is weighed and the change in weight during immersion is used to determine the corrosion rate. It could be easily observed that with increasing time and concentration the colour of the sample surface turns to darker. It is expected that mostly silicon from the alloy will remain on its surface; however, this will have to be proven by a detailed SEM-EDX analysis.

Two points are marked with black circles: one after testing in 0.1% sulphuric acid for 48h, the other one at 1% for 60h. Their corrosion rates seem to be a little higher than the others in these investigations. The most possible reason which can be observed at the sample surface (small dots dispersed at surface), should be pitting corrosion.

From SEM images of corroded surfaces under different conditions, a cursory observation was given: the darker area must be mainly aluminum phase, the lighter area should consist mostly of silicon phase; as the corrosion duration increases, the lighter parts become larger; as the sulfuric acid concentration increases, the lighter parts become denser.

This corrosion type is supposed to be dealloying (dealumination): selective removal of aluminum from the surface, and a percolating cluster of silicon atoms provides a continuous active pathway for the corrosion process as well as a pathway for the electrolyte to penetrate the solid.

It can also be concluded that grain structure defects (like porosity) can affect the corrosion mechanism.

Discussion

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