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

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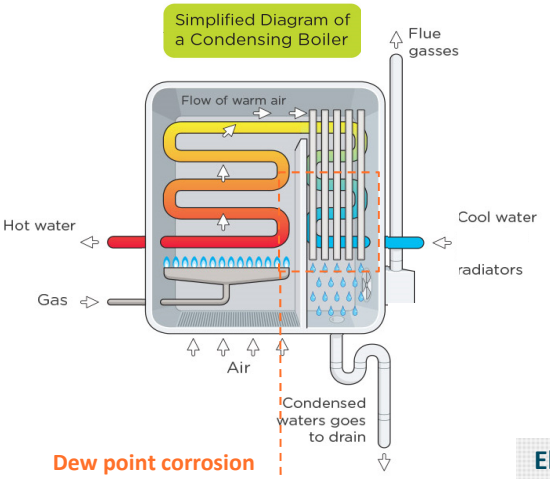
Background

Condensing boilers are highly efficient heating boilers on the market. Due to the formation of acidic condensate, heat exchangers and drain systems are **contaminated and/or clogged** easily with corrosion products.

A better understanding of the underlying processes leading to corrosion of such systems should be obtained.



Methods

Immersion corrosion tests in diluted and concentrated sulfuric acid.

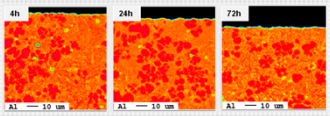
The **corrosion mechanism** was investigated by immersion test, OCP and EIS, AFM and SKPFM, EPMA/WDX.

The **corrosion products** were analyzed by XRD, SEM/EDS, Raman, and EPMA/WDX.

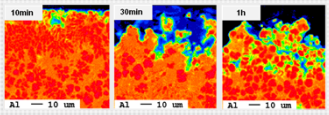
A dew point corrosion setup was developed to simulate typical load conditions.

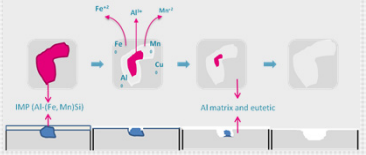
Immersion tests

0.1% H_2SO_4 at 40°C



30% H_2SO_4 at 80°C

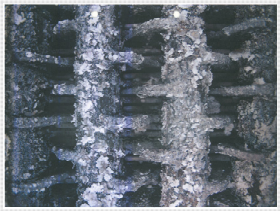




Based on the EPMA and AFM observations, Intermetallics dissolved at a faster rate than the other phases in acidic solutions.

Dew point corrosion

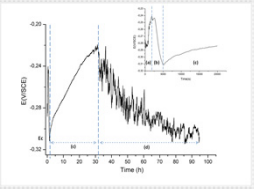
Corrosion mechanism research

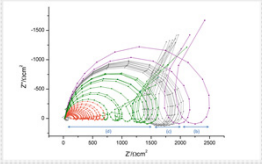


The main parameters for producing the several possible corrosion products should be derived.

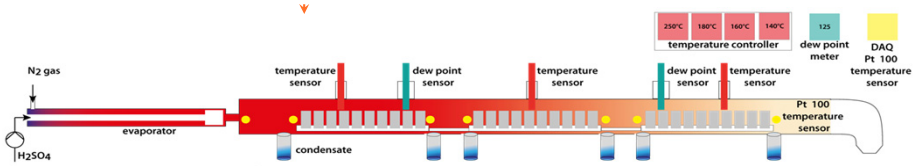
Model

Electrochemical analysis

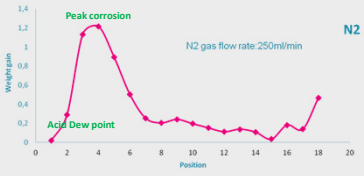


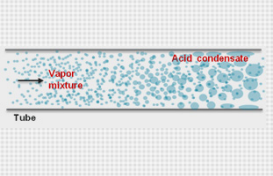


Both pH value and Intermetallics influencing are investigated on the corrosion mechanism in diluted acid.



Dew point corrosion tests





- Dew point of sulfuric acid

$$\frac{1}{T} = 0.002276 - 0.00002943 ln p_w - 0.0000858 ln p_\pi + 0.00000620 (ln p_w \times ln p_\pi)$$

- Heat transfer

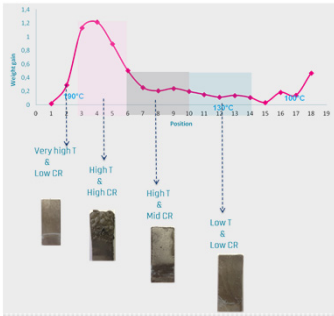
$$Q_{max} = m_g \times Cp_g \times (T_{gin} - T_{win})$$

- Condensation rate

$$\dot{m} = \frac{\dot{Q}}{h_{fg}}$$

T= Temperature
Π=mass fraction of H_2SO_4 in liquid
p_π=partial pressure of H_2SO_4 in flue gas
p_w=partial pressure of water vapor in flue gas
Total pressure = $p_\pi + p_w$

m_g= mass flow rate of gas
C_{pg}= specific heat of gas
T_{gin}= inside temperature of gas
T_{go}= outside temperature of gas
T_{dew}= dew point temperature of vapor
m= condensation rate
Q= heat transfer
H_{fg}= latent heat of condensation



The corrosion rate is not only governed by the rate of acid deposition but also by the other factors.

Condensation rate (CR) analysis

Influence of the gas velocity on the condensation rate.

Influence of temperature of the gas phase on the condensation rate.

Corrosion rate analysis

Influence of the condensation rate on the corrosion rate.

Influence of local temperature on the corrosion rate.

Influence of corrosion products on the corrosion rate.

Is this study succeeding?

Yes, in-depth understanding of corrosion mechanisms under various acidic conditions is given, and a stable dew point corrosion test set-up can be used for future work.