Effect of Thickness of Water Film on Corrosion Behavior of Carbon Steel in Marine Atmosphere

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The relative humidity, RH, in equilibrium with solutions for various concentrations of sea salt could be calculated by using available thermodynamic data [1].

To confirm the relationships between chemical composition of water film and RH in actual environment, amount of absorbed moisture was measured. Stainless steel sheets and QCM, Quartz Crystal Microbalance, [2] were covered with given amount of simulated sea salt, \( W_s \), which contained NaCl and MgCl\(_2\) • 6H\(_2\)O; \( m[\text{Mg}^{2+}/\text{m}[\text{Na}^+] = 0.11 \) [3], and were exposed in the constant humidity chamber for 2 – 4 h. The amount of absorbed moisture, \( W_{as} \), was determined as weight change during the exposure.

Relationships between the ratios of \( W_{as}/W_s \) and RH are shown in Fig.1. The value of \( W_{as}/W_s \) is also given as follows [1]:

\[
(W_{as}/W_s) = \frac{(1000s/M_r) + 6sM_e}{M_t} \quad (1)
\]

where \( s=6[\text{Mg}^{2+}/\text{m}[\text{Na}^+] = 0.11 \), \( m_1 \) is concentration of \( \text{MgCl}_2 \), and \( M_1 \), \( M_2 \) and \( M_e \) are molecular weights of \( \text{NaCl} \), \( \text{MgCl}_2 \) and water, respectively. This calculated value of \( W_{as}/W_s \) is also plotted in the figure, and it agreed well with measured data, when \( W_s \geq 10^{-2}\text{g/m}^2 \).

This is in proportion to \( W_s \), when \( W_s \geq 10^{-2}\text{g/m}^2 \).

Relationships between thickness of water film, \( d \), and RH under various \( W_s \) conditions are shown in Fig.2. The values of \( d \) were calculated as follows [1]:

\[
d = \sqrt{sW/(M_rM_{\text{atm}} + 6sM_e)} \quad (2)
\]

where \( r_s \) is specific gravity of the solution, and \( m_1 \) is concentration of NaCl.

Carbon steel coupons and QCM sensors [4] were sprayed with diluted sea water and dried to deposit given amount of sea salt on them. Carbon steel coupons were exposed in the constant humidity chamber for 1 month. As for QCM sensors, time variations of them were measured in the constant humidity chamber for 2 – 3 h, and corrosion rate, \( \Delta L/\Delta t \), was determined as;

\[
(\Delta L/\Delta t) = (1\text{Fe}) (M_e/M_{\text{atm}}) (\Delta m/\Delta t) \quad (3)
\]

where \( M_e \) and \( M_{\text{atm}} \) are molecular weights of Fe and \( \text{Fe(OH)}_2 \), \( r_s \) is density of Fe, \( r_{\text{m}} = 7.86\text{g/cm}^3 \), and \( (\Delta m/\Delta t) \) is mass change measured by QCM sensor. In this work, the primary corrosion product of Fe was considered to be \( \text{Fe(OH)}_2 \).[4]

Exposure test results are shown in Fig. 3 in terms of corrosion rate, \( CR[\text{mm}^2/\text{y}] \), and thickness of water film, \( d \). The value of \( CR \) increases with increasing \( d \) when \( d<56\mu \text{m} \). It reaches up to the maximum of \( CR=0.28\text{mm}^2/\text{y} \) at \( d=56\mu \text{m} \), and it takes the constant value of \( CR=0.16\text{mm}^2/\text{y} \) when \( d>170\mu \text{m} \).

References

![Fig. 1 Relationship between \( W_{as}/W_s \) and RH.](image)

![Fig. 2 Relationship between \( d \) and RH under various \( W_s \) conditions.](image)

![Fig. 3 Effect of \( d \) on \( CR \) under various conditions.](image)