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 $MgCl_2 \cdot 6H_2O$; $m[Mg^{2+}]/m[Na^+] = 0.11$ [3], and were exposed in the constant humidity chamber for 2 ~ 4 h. The amount of absorbed moisture, W_{ab}, was determined as weight change during the exposure.

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

$$(W_{ab}/W_s)=\{(1000s/m_2)-6sM_w\}/M_t \qquad (1)$$

$$M_t= M_1+ s M_2+ 6s M_w$$

where $s=m[Mg^{2+}]/m[Na^+]=0.11$, m_2 is concentration of $MgCl_2$, and M_1, M_2 and M_w are molecular weights of NaCl, $MgCl_2$ and water, respectively. This calculated value of (W_{ab}/W_s) is also plotted in the figure, and it agreed well with measured data, when $W_s \geq 10^{-2} g/m^2$. Thus, *d* is in proportion to W_s when $W_s \geq 10^{-2} g/m^2$.

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];

$$d=(sW_s/M_t \boldsymbol{r}_s)\bullet\{(M_1 m_1/m_2)+M_2+(1000/m_2)\} \quad (2)$$

where $\boldsymbol{r}_s$ 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;

$$(\Delta L/\Delta t)=(1/\boldsymbol{r}_{Fe})\bullet(M_{Fe}/M_{(OH)x})\bullet(\Delta m/\Delta t) \quad (3)$$

where M_{Fe} and $M_{(OH)x}$ are molecular weights of Fe and $(OH)_x$, $\boldsymbol{r}_{Fe}$ is density of Fe, $\boldsymbol{r}_{Fe} = 7.86 g/cm^3$, 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 $Fe(OH)_{2.5}$ [4].

Exposure test results are shown in Fig. 3 in terms of corrosion rate, *CR*[mm/y], and thickness of water film, *d*. The value of *CR* increases with increasing *d* when d<56μm. It reaches up to the maximum of *CR*=0.28mm/y at *d*=56μm, and it takes the constant value of *CR*=0.16mm/y when *d*≥170μm.

References
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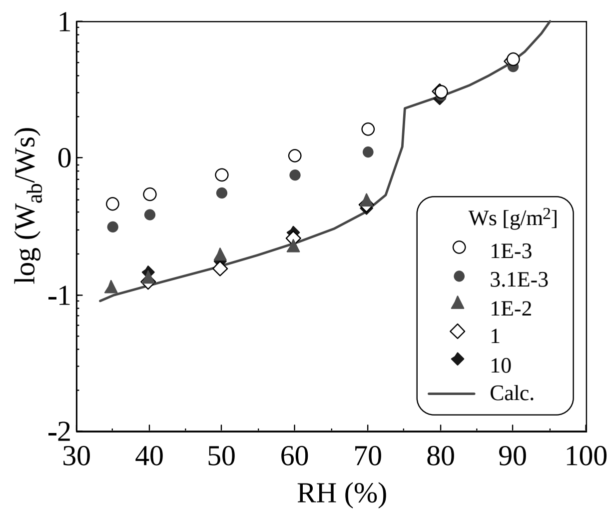

Fig. 1 Relationship between (W_{ab}/W_s) and *RH*.

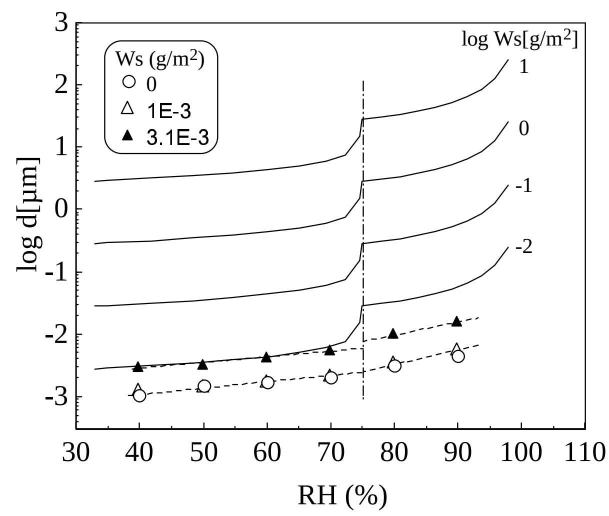

Fig.2 Relationship between *d* and *RH* under various W_s conditions.

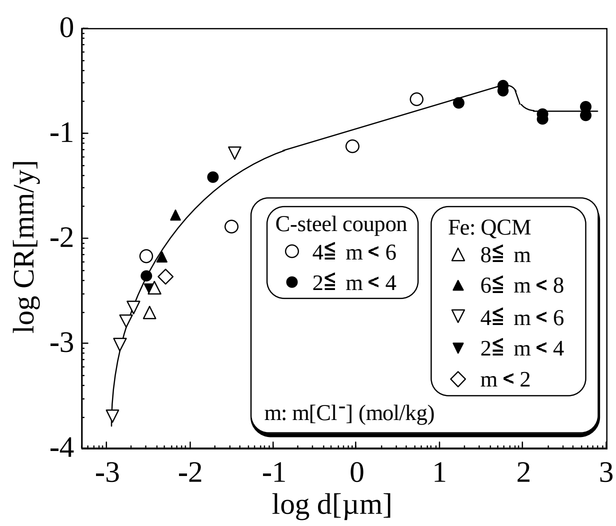

Fig.3 Effect of *d* on *CR* under various conditions.