A NOTE ON THE MODELING OF CORROSION RATES OF MILD STEEL, MEDIUM CARBON STEEL, BRASS AND ALUMINUM

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ABSTRACT

Results of earlier corrosion experiments on mild steel, medium carbon steel, brass and aluminum exposed to the laboratory atmosphere and 0.1M solutions of sodium chloride, ammonium hydroxide and hydrochloric acid were used to obtain second order regression equations of corrosion extents for varying exposure times. In the present study expressions for corrosion rates are derived from the regression equation obtained for each experiment. The corrosion rates are useful in determining how fast corrosion takes place at any given instant of exposure time, within the limits of experimental values.

Keywords: Corrosion rate equations, Steel, Brass, Aluminum.

INTRODUCTION

In earlier experiments (Sodiki, 1996; Sodiki, 2015) the extent of corrosion over time of specimens of mild steel, medium carbon steel, brass and aluminum exposed to the laboratory atmosphere and 0.1M solutions of sodium chloride, ammonium hydroxide and hydrochloric acid were measured by the weight change method (Ailor, 1971; Chapman, 1964; Tan et al, 1995). The chemical compositions of the test metals are given in Table 1. The experimental procedures which involved preparation of the test metals and exposure environments, and corrosion measurement had been elaborated earlier (Sodiki, 1996; Sodiki, 2015).

Table 1: Chemical Compositions of Test Metals

Mild steel	Iron	Carbon	0.150
		Sulphur	0.023
		Phosphorus	0.030
		Manganese	0.500
		Silicon	0.250
Medium carbon steel	Iron	Carbon	0.350
		Sulphur	0.020
		Phosphorus	0.035
		Manganese	0.600
		Silicon	0.170
Brass	Copper	Zinc	30
Aluminium	Aluminium	Iron	0.7
		Manganese	0.1
		Silicon	0.5

The results of those experiments were subsequently utilized to obtain regression equations for predicting the corrosion extents of the test metals with time in the different environments

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(Sodiki and Ndor, 2016; Sodiki et al, 2016). Calculated correlation coefficients indicate reasonable agreement between the results given by the equations and the experimental values of extent of corrosion. In the present study, the rates (as distinct from the extents) of corrosion are calculated from the regression equations, as the gradients of the equations. These rates are useful in determining how fast corrosion takes place after a given exposure time period.

CALCULATION OF CORROSION RATES

In general, the extents of corrosion denoted as y, as computed from the regression equations, were given in terms of time denoted as t, by second order polynomials as (Kreysig, 1999; Lipson and Sheth, 1973)

$$y = a_0 + a_1 t + a_2 t^2 \quad \text{- - - -} \quad (1)$$

Thus, the corrosion rate R becomes

$$R = \frac{dy}{dt} = a_1 + 2a_2 t \quad \text{- - - -} \quad (2)$$

The corresponding rates obtained for the different test metals and environments are, hence, listed in Table 2.

Table 2: Calculation of Corrosion Rates from Regression Equations

Corrosion Experiment	Regression Equation	Corrosion Rate Equation
M.S.* in Laboratory Atmosphere	$y = 2.270 + 0.0124t + 1.366 \times 10^{-5}t^2$	$R = 0.0124 + 2.732 \times 10^{-5}t$
M.S. in 0.1M NaCl	$y = 2.277 + 0.0416t - 2.980 \times 10^{-5} t^2$	$R = 0.042 – 5.960 \times 10^{-5}t$
M.S. in 01M NH_4OH	$y = -7.047 + 0.19t - 2.948 \times 10^{-4} t^2$	$R = 0.190 – 5.896 \times 10^{-4}t$
M.S. in 0.1M HCl	$y = 38.960 + 0.0293t + 6.079 \times 10^{-4}t^2$	$R = 0.029 + 1.216 \times 10^{-3}t$
M.C.S.* in Laboratory Atmosphere	$y = 0.297 + 2.403 \times 10^{-3}t - 4.376 \times 10^{-6} t^2$	$R = 2.403 \times 10^{-3} – 8.752 \times 10^{-6}t$
M.C.S. in 0.1M NaCl	$y = 3.225 + 0.076t + 2.245 \times 10^{-5} t^2$	$R = 0.076 + 4.490 \times 10^{-5}t$
M.C.S. in 0.1M NH_4OH	$y = -0.736 + 0.105t - 6.085 \times 10^{-5} t^2$	$R = 0.105 – 1.217 \times 10^{-4}t$
M.C.S. in 0.1M HCl	$y = 33.970 + 0.295t – 6.793 \times 10^{-4} t^2$	$R = 0.295 – 1.359 \times 10^{-3}t$
Brass in Laboratory Atmosphere	$y = 0.275 + 2.629 \times 10^{-3}t - 4.543 \times 10^{-6} t^2$	$R = 2.629 \times 10^{-3} – 9.086 \times 10^{-6}t$
Brass in 0.1M NaCl	$y = -1.666 \times 10^{-3} + 0.017t - 4.612 \times 10^{-5} t^2$	$R = 0.017 – 9.224 \times 10^{-5}t$
Brass in 0.1M NH_4OH	$y = 0.129 + 0.011t - 2.991 \times 10^{-5} t^2$	$R = 0.011 – 5.982 \times 10^{-5}t$
Brass in 0.1M HCl	$y = 1.561 + 0.065t + 7.145 \times 10^{-5} t^2$	$R = 0.065 + 1.429 \times 10^{-4}t$
Aluminum in Laboratory Atmosphere	$y = 1.726 + 8.286 \times 10^{-5} t + 3.775 \times 10^{-7} t^2$	$R = 8.286 \times 10^{-5} + 7.550 \times 10^{-7}t$
Aluminum in 0.1M NaCl	$y = 0.081 + 6.268 \times 10^{-3} t - 8.395 \times 10^{-6} t^2$	$R = 6.268 \times 10^{-3} – 1.679 \times 10^{-5}t$
Aluminum in 0.1M NH_4OH	$y = 0.281 + 1.332 \times 10^{-5} t + 4.670 \times 10^{-6} t^2$	$R = 1.332 \times 10^{-5} + 9.340 \times 10^{-6}t$
Aluminum in 0.1M HCl	$y = 0.288 + 0.059t - 4.528 \times 10^{-5} t^2$	$R = 0.059 – 9.056 \times 10^{-5}t$

M.S*: Mild Steel, M.C.S*: Medium Carbon Steel

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DISCUSSION OF RESULTS

In a large number of the corrosion experiments, there are decreases in corrosion rates (indicated by the negative coefficients of t) as time passes. This is expected, as the initial corrosion products usually provide some surface protection against further attack. This trend is also enhanced, in the experiments involving the 0.1M solutions, by the progressive reduction of the concentrations of the reacting constituents in solution.

In the other experiments in which increasing, or nearly constant, corrosion rates were observed, the protective effect of the surface and the progressive weakening of the exposure environments were not yet noticed due to the generally short exposure times utilized.

CONCLUSIONS

Corrosion rate equations, which determine how fast a given metal deteriorates due to corrosion in an exposure environment at any given time, have been obtained, within the limits of experimental values. Similarly, other equations utilizing different metals with various compositions and parameters, exposure environments, and exposure time durations could be obtained.

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