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Research Article

DIFFERENTIAL PRESSURE TRANSDUCER FOR CORROSION MONITORING ON IRON

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Abstract

In this study, differential pressure transducer (DPT) has been applied as an alternate corrosion monitoring device for monitoring corrosion of iron in atmospheric environment by measuring very small changes in the amount of oxygen. The result of corrosion current obtained from DPT method has been compared with that obtained from AC impedance method. The difference in the value of corrosion current obtained from these two methods was attributed to the error in choosing the value of proportionality constant k of the Stern-Geary equation.

Keywords: Atmospheric Corrosion; Differential pressure transducer; AC impedance; Corrosion current

Introduction

Corrosion monitoring in atmospheric environment has always been a challenge as it requires electrochemical set up to be used in very thin layer of electrolyte (Yadav *et al*., 2004). In thin electrolyte layer, the electrochemical method is limited due to very high solution resistance. Therefore, traditionally mass loss method has been used to estimate the corrosion rate of materials exposed in outdoor environment. However, this requires long time and it does not give instantaneous corrosion rate to understand the mechanism of corrosion. Electrochemical method based on the AC impedance method has been used for monitoring atmospheric corrosion using 2-electrode cell where the gap between two electrodes is kept very small, in the range of micrometer to minimize the ohmic drop resulting (Nishikata *et al*., 1995). AC impedance method employs two frequency measurements viz, high frequency (10kHz), Z_L and low frequency (10mHz), Z_H. The polarization resistance, R_p is obtained by subtracting Z_H from Z_L. This is based on the assumption that high frequency impedance gives the solution resistance and low frequency impedance provides a sum of solution resistance and polarization resistance. The corrosion current density i_{corr} is proportional to the value of R_p^{-1}, according to Stern and Geary equation (Stern *et al*., 1957).

$$i_{\mathrm{corr}} = k / R_{\mathrm{p}} \qquad (1)$$

The proportionality constant k can be calculated from the Tafel slopes b_a and b_c of the anodic and cathodic portion of the polarization curves respectively, as given in the eq. (2).

$$k = b_{\mathrm{a}} b_{\mathrm{c}} / 2.303(b_{\mathrm{a}} + b_{\mathrm{c}}) \qquad (2)$$

However, the distinct Tafel regions, in corrosion systems, do not always appear on the polarization curves and the estimation of k value becomes difficult (Walter, 1991). Thus, it is preferable that the k value should be determined in advance from the correlation between the measured R_p^{-1} and i_{corr} determined from weight loss measurement.

However, under a thin layer of electrolyte like those involved in the atmospheric corrosion environments, it is much more difficult to measure accurate polarization curves over wide potential ranges. Therefore, this study reports on the applicability of differential pressure transducer (DPT) as an alternate method for the estimation of corrosion rate of iron corroding in thin electrolyte layer.

Materials and method

Differential pressure transducer (DMT)

Differential pressure transducer senses very low differential pressure and convert this pressure difference to a proportional electrical output for either unidirectional or bi-directional pressure ranges. In this study, a Setra System 264 pressure transducer was used to measure the amount of oxygen consumed during iron corrosion in a 0.05M NaCl solution. The Model 264 voltage output can operate from 9-30 VDC excitation and it has a 0-5 VDC output. The current output is 4-20mA and it can sense the pressure difference up to ±12.7mmH_2O. Static standard accuracy is ±1.0% full scale in normal ambient temperature environments.

The experimental set-up for the measurement of oxygen consumption by differential pressure meter is shown in Fig.1. All the components of the set-up were made up of acrylic sheets. The oxygen consumption was measured on the as polished iron sample. The as polished sample was obtained by polishing it through #600 silicon carbide paper, rinsed with double distilled water, cleansed ultrasonically in ethanol and finally washed with double distilled water and dried in a pulse of warm air.

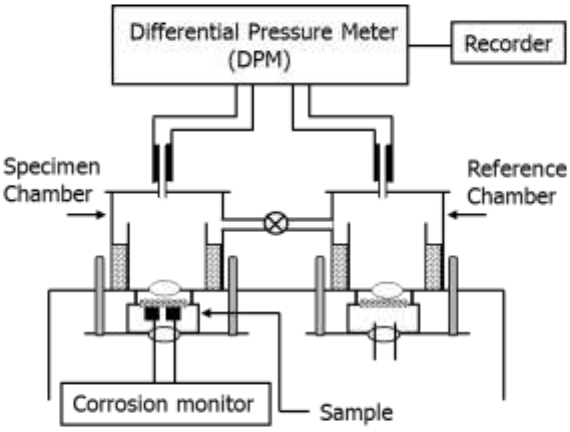

Fig. 1: Schematic diagram of the experimental set-up used for measuring oxygen consumption using a differential pressure meter.

The test sample with an electrolyte layer thickness of 500µm (0.05M NaCl) was placed in the specimen chamber, kept at constant temperature, and the difference in the pressure was recorded against the reference chamber, which was prevented from corrosion by using an epoxy resin. Then, the corrosion rate was calculated by using the following equation (Stratmann *et al.*, 1990).

$$i_{\mathrm{corr}}(\mathrm{O}_2) = \frac{4\mathrm{FV}}{\mathrm{RTA}}\frac{\Delta P}{\Delta t} \qquad (3)$$

Here, F is the Faraday's constant, V the volume of the specimen chamber, R the gas constant, T the absolute temperature, A the surface area of the sample and ΔP the pressure difference between specimen and reference chambers in the time interval of Δt. Both the chambers were filled with a water reservoir containing 0.05M NaCl. These reservoirs keep the partial pressure of H_2O at a constant value inside the chambers, and hence, minimize the evaporation of the electrolyte layer during the measurement.

The impedance was measured using an AC corrosion monitor (RIKEN DENSHI CT-7) with a multiplexer controlled by a personal computer. Special software was used for the data acquisition at the time interval of 10 min.

The i_{corr} was calculated from the measured impedance at 10mHz using the relation,

$$i_{corr} = k / Z_{10\mathrm{mHz}} \qquad (4)$$

A special arrangement of electrodes was made in order to measure the impedance and amount of oxygen consumed during corrosion in the same time, Fig. 2. For this, a pair of iron plate was mounted in an ambient temperature solidifying epoxy resin with the separation gap of 0.2 mm. Before embedding the iron plates into the epoxy resin, they were subjected to electro-deposition coating employing an organic resin for 3 min followed by curing at 170 °C for 20 min. This was done to prevent the occurrence of crevice corrosion at the sides of the specimen. Another iron plate with a larger surface area (2.4cm^2) was also mounted together with the probe in order to increase output response of the differential pressure meter.

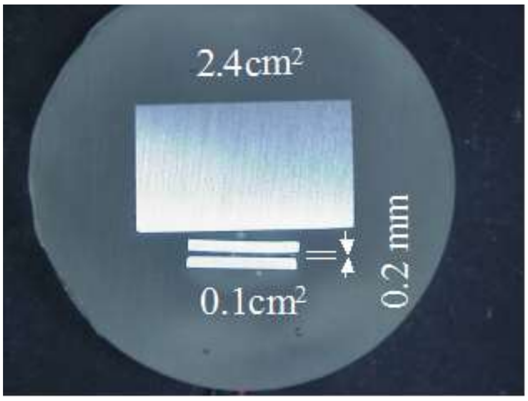

Fig. 2: Schematic diagram of the experimental cell used for monitoring of impedance and measuring oxygen consumption.

Results and discussion

Calibration of DPM

Differential pressure meter is very sensitive to the temperature changes. A small difference of temperature, ΔT = 0.1°C between specimen chamber and reference chamber can cause a pressure difference (ΔP) of 6.7x10^{-6}atm, which corresponds to a corrosion rate of approximately 3.0 µA cm^{-2}. Therefore, a blank test was performed to check the influence of the temperature on the measurement. Both the chambers were prevented from corrosion using epoxy resin and the change in the pressure was measured at the slight variation of temperature. The result is shown in Fig. 3. As evident from Fig. 3, change of pressure is very small even though the temperature of the surroundings of the chambers is changed by about 2.0^{0}C during the measurement. This indicates that both the chambers were maintained at almost same temperature and a slight variation of temperature has no influence on the measured corrosion current. From this system, $i_{\mathrm{corr}}(\mathrm{O}_2)$ can be measured down to 2µA cm^{-2}.

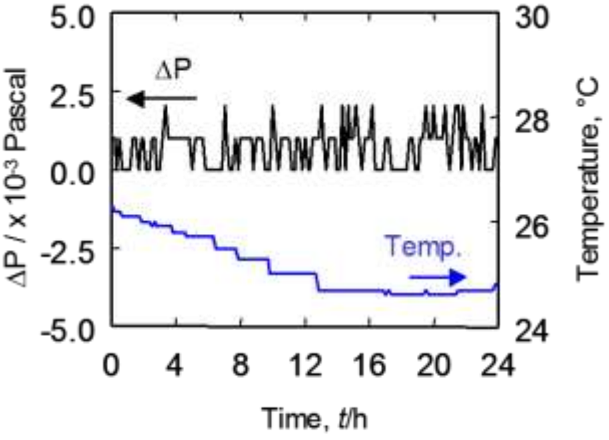

Fig. 3: Changes in partial pressure with the change of temperature of surrounding as the epoxy resins placed in the both chambers.

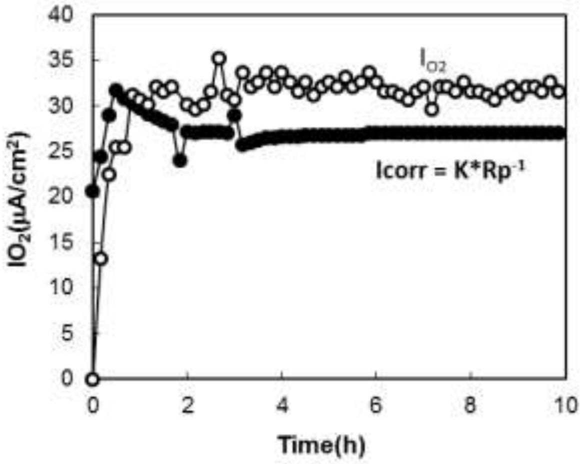

Fig. 4: Changes in $i_{corr}(O_2)$ and Z_{10mHz}^{-1} of the as polished sample, kept at constant temperature, under 200 and 500□m thick layer of 0.05M NaCl solution.

Corrosion monitoring by DPT

Monitoring results of corrosion current, i_{corr} (O_2) obtained from DPT and reciprocal of impedance at 10mHz (Z_{10mHz}^{-1}) of the as polished zinc iron sample covered with 500μm thick electrolyte layer are shown in Fig.4. To obtain the corrosion current from reciprocal of impedance at 10mHz, the value of proportionality constant k in equation (4) was fixed at 20mV. This value can be reasonably taken for activation control anodic dissolution of iron and diffusion control oxygen reduction reaction in nearly neutral salt medium. The change in corrosion current obtained by the two methods differs by about 5μA.

The corrosion current values of the two methods were found to be close to each other in the beginning of the corrosion only. After about two hours of corrosion the difference became obvious. However, in the very early stage of corrosion the data could not be reliable due to establishing of equilibrium where relative humidity of both the chamber becomes equal. Therefore, the difference in the corrosion current values obtained by the two methods can be related to the value of k that was used to estimate the corrosion current from reciprocal of impedance at 10mHz as DPT measures the amount of oxygen consumed in cathodic reaction and therefore it gives the direct corrosion current provided there is no any other oxidizing agent. It seems that with the progress of corrosion and formation of rust layer, the value of k changes due to change in the polarization behavior of the corroding surface.

Conclusion

A Differential pressure transducer was used successfully to estimate the oxygen consumption rate (i_{corr} (O_2)) of iron in near neutral chloride solution. At the initial stage, the obtained i_{corr} (O_2) was comparable to corrosion current estimated from reciprocal of the impedance at 10mHz (Z_{10mHz}^{-1}), and the proportional constant k equal to 20mV. The difference in the value of corrosion current obtained from DPT and AC impedance method was obtained with the progress of corrosion. This difference was related to the deposition of corrosion products on the corroding surface.

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References

Nishikata A, Ichihara Y, Tsuru T (1995) An Application of Electrochemical Impedance Spectroscopy to Atmospheric Corrosion Study. *Corros. Sci*. 37: 897-911. DOI: 10.1016/0010-938X(95)00002-2

Stratmann M, Streckel H (1990) On the Atmospheric Corrosion of Metals which are Covered with Thin Electrolyte Layers—I. Verification of The Experimental Technique. *Corros. Sci*. 30: 681-696. DOI: 10.1016/0010-938X(90)90032-Z

Stern M, Geary AL (1957) Electrochemical Polarization: I. A Theoretical Analysis of the Shape of Polarization Curves. *J. Electrochem. Soc.*104: 56-63. DOI: 10.1149/1.2428496

Walter W (1991). Laboratory Simulation of Atmospheric Corrosion by SO_2-I. Apparatus, Electrochemical Techniques, example results. *Corros. Sci*. 32: 1331-1352. DOI: 10.1016/0010-938X(91)90052-Q

Yadav AP, Nishikata A, Tsuru (2004) Electrochemical Impedance Study on Galvanized Steel Corrosion Under Cyclic Wet–Dry Conditions-Influence of Time of Wetness. *Corros. Sci*. 46: 169-181. DOI: 10.1016/S0010-938X(03)00130-6