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Determination of galvanic corrosion rate for assembled forms of carbon fibre reinforced plastics (CFRPs) and protection-coated metal — Electrochemical tests in neutral sodium chloride solution

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Détermination du taux de corrosion galvanique pour les formes assemblées de plastiques renforcés de fibres de carbone (CFRP) et de métal revêtu de protection — Essais électrochimiques en solution neutre de chlorure de sodium

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Foreword

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This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

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Determination of galvanic corrosion rate for assembled forms of carbon fibre reinforced plastics (CFRPs) and protection-coated metal — Electrochemical tests in neutral sodium chloride solution

1 Scope

1.1 This document specifies the electrochemical test for determining galvanic corrosion rate of CFRPs and metal assemblies with protection-coating, subjected to the corrosive environment of electrolyte diffusion through the coating. It specifies the apparatus, the test solutions, and the procedure to be used in conducting the electrochemical tests for

a) the assessment of the Fick's diffusion parameter for protective coating on metallic materials, and

b) the estimation of the galvanic corrosion rates with the conversion of ISO 21746 coating-free sample data.

1.2 The following are intended situations of implementing an electrochemical test based on this document:

a) when interested parties estimate the galvanic corrosion rate of bonded joints relating engineering metals with protection-coating and CFRPs of the potential drastically nobler than those of most metals, utilizing the resources of ISO 17475;

b) when expanding CFRP-metal bonded joints applications using coatings to the fields of corrosion-sensitive environments caused by electrolytes.

1.3 It is not the intent of this document to fulfil the need for:

— omitting relevant field tests for the applications in corrosive environment;

— superimposing test data for specific applications for the range of relevant data;

— comparative testing as a means of ranking different protections with respect to corrosion rates;

— ignoring the field hazards such as erosion, abrasion, and ultraviolet irradiation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2808, Paints and varnishes — Determination of film thickness

ISO 17475, Corrosion of metals and alloys — Electrochemical test methods — Guidelines for conducting potentiostatic and potentiodynamic polarization measurements

ISO 21746, Composites and metal assemblies — Galvanic corrosion tests of carbon fibre reinforced plastics (CFRPs) related bonded or fastened structures in artificial atmospheres — Salt spray tests

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obphttps://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/https://www.electropedia.org/

4 Symbols

t_0: flux onset time

t_1: upper bound time of linear section in time-charge plot

Q: charge at a time t

Q_0: charge at linearly extrapolated time point t_0

D: Fick's diffusion parameter

a: slope of Q-t plot

b: error in Q-t plot owing to charge duration and other factors

d: coating thickness

E_{cr}: estimation of galvanic corrosion rate for coated sample

K_{cr}: galvanic corrosion rate of coating-free sample derived with ISO 21746

F_{pe}: protection efficiency

D_{ox}: oxygen diffusion constant in water

x_{DL}: the diffusion layer thickness of air saturated static water

C: static capacity of capacitor

ε_0 : permittivity of vacuum

ε_r : relative permittivity

S: gird area of capacitor

x: inter-grid distance of capacitor/ locational dimension in flux direction

V: inter-grid potential of capacitor

J: the diffusion flux

$c(x)$: electrolyte density function

J_{PC}: steady flux through thin protective coating

J_{PCO}: oxygen flux through protection coating

J_{PFO}: oxygen flux for protection free sample

J_{ASO}: oxygen flux in air saturated static water

J_{OMax}: the maximum through coating flux of oxygen in the form of water solution

c_O: saturated oxygen density in water

x_{DL}: diffusion layer thickness

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D_{ox}: oxygen diffusion constant in water

a	slope of Q-t plot
b	error in Q-t plot owing to charge duration and other factors
C	static capacity of capacitor
c_0	saturated oxygen density in water
$c(x)$	electrolyte density function
d	coating thickness
D	Fick's diffusion parameter
D_{ox}	oxygen diffusion constant in water
E_{cr}	estimation of galvanic corrosion rate for coated sample
F_{pe}	protection efficiency
J	diffusion flux
J_{ASO}	oxygen flux in air saturated static water
J_{PC}	steady flux through thin protective coating
J_{PCO}	oxygen flux through protection coating
J_{PFO}	oxygen flux for protection free sample
J_{OMax}	the maximum through coating flux of oxygen in the form of water solution
K_{cr}	galvanic corrosion rate of coating-free sample derived with ISO 21746
Q	charge at a time t
Q_0	charge at linearly extrapolated time point t_0
S	gird area of capacitor
t_0	flux onset time
t_1	upper bound time of linear section in time-charge plot
V	inter-grid potential of capacitor
x_1	inter-grid distance of capacitor
X_2	locational dimension in flux direction
x_{DL}	the diffusion layer thickness of air saturated static water
x_{DL}	diffusion layer thickness
ε_0	permittivity of vacuum
ε_r	relative permittivity

5 Principle

5.1 General

Protection coating behaves as a capacitor in the form between conductive materials and conductive electrolytes. Focusing on the capacitance, Fick's diffusion parameter is monitored by analysing the drift in charge due to the distance shrinkage with water absorption from the surface of the protective coating

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in the plate-shaped sample. The effect of the protective coating is evaluated by converting the value into the salt spray flux in the galvanic corrosion test.

5.2 Capacitor model

Static capacity, C, of a capacitor in ~~Figure A.1~~Figure A.1 is expressed as ~~Formula (1):~~Formula (1):

~~$C = \varepsilon_r \varepsilon_0 \frac{S}{x}$ (1)~~

~~Where, $\varepsilon_0 = 8{,}854\,187\,62 \times 10^{-12}$~~ $$C = \varepsilon_r \varepsilon_0 \frac{s}{x_1} \quad (1)$$

where $\varepsilon_0 = 8{,}854\,187\,62 \times 10^{-12}$ is the permittivity of vacuum~~, ε_r is relative permittivity, S is grid area, and x is inter-grid distance.~~.

The charge, Q, is expressed as follows when inter-grid potential, V, is loaded.

~~$Q = CV$~~ $$Q = CV \quad (2)$$

~~The Formulae (1) and (2)~~Formulae (1) and (2) lead to ~~an~~the following expression~~ as follows~~.

~~$Q = \varepsilon_r \varepsilon_0 \frac{SV}{x}$~~ $$Q = \varepsilon_r \varepsilon_0 \frac{sV}{x_1} \quad (3)$$

When the inter-grid distance x shrinks to ~~x-Δx~~x_1-Δx_1 through diffusion, the charge drift ΔQ is expressed using ~~Formula (3)~~Formula (3) as follows.

~~$x\Delta Q + Q\Delta x = 0$~~ $$x_1 \Delta Q + Q \Delta x_1 = 0 \quad (4)$$

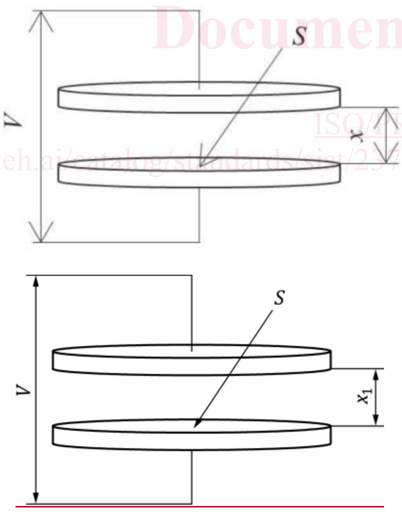

Figure 1 — Schematic diagram of capacitor

A capacitor in ~~Figure 1~~Figure 1 is expressed as is shown in ~~Figure 2~~Figure 2 for a grid of conductive base material, a grid of electrolyte, and thin coating with the thickness ~~x~~x_1 to separate the grids.

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