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Corrosion Processes below Organic Coatings

Sigunde Pietsch, Wolf-Dieter Kaiser

Institut for Corrosion Protection Dresden, Gostritzer Str. 61-63, 01217 Dresden, Germany

Summary: The protective mechanisms of paint systems of a 1-pack polyurethane- and an epoxy/2-pack polyurethane-coating system with zinc dust priming coats were investigated on blast-cleaned and on hand-cleaned steel substrates. The coated panels were exposed to the salt spray test and to a cyclic alternating test (VDA 621-415). The protective effect was assessed in determining adhesion, undermining at scratches, water uptake and the corrosion potential.
On blast cleaned steel substrates the adhesion of the investigated coating systems was not influenced by water uptake of the coatings. Scratches are especially cathodically protected. On hand-cleaned steel surfaces the rust layer between steel substrate and coating can participate in the corrosion process with rust reduction as cathodic partial reaction. The change of rust morphology is the reason for the loss of adhesion of coating. At scratches rust reduction takes also place at the edge of the defect which is independent from pigments of the base coating.

Keywords: adhesion, coatings, electrochemistry, zinc dust pigments, dielectric properties

Introduction

Corrosion processes below organic coatings are responsible for widespread damages of coated steel constructions. Normally these proccesses are electrochemical reactions. Therefore electrochemical methods are suitible for investigation of such processes. In this paper classical and electrochemical methods are used for investigation of the protective mechanisms of corrosion-protective paints.

Experimental

Paint systems

Paint systems of a moisture cured 1-pack polyurethane- and an epoxy/2-pack polyurethane-coating system with zinc dust priming coats were investigated on blast-cleaned (preparation grade Sa $2^1/_2$) and on hand-cleaned (preparation grade St 2) steel substrates (table 1).

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Table 1. Paint systems

System-No.	Priming coat		Top coat	Paint system
	Binder	Pigment	Binder	Dry Film Thickness µm
1	1-pack polyurethane	zinc dust	1-pack polyurethane	200
2	epoxy	zinc dust	epoxy / 2-pack polyurethane	240

Exposure conditions

The coated panels were exposed to the neutral salt spray test (DIN ISO standard 7253) and to a cyclic alternating test consisting of periods of neutral salt spray, humid atmosphere and dry atmosphere (VDA standard Nr. 621-415).

Assessment of the protective effect

The protective effect was assessed in determining adhesion, undermining at scratches, wateruptake and the corrosion potential (table 2). All of these parameters were investigated in dependence of the exposure time.

Table 2. Paint system assessment

Parameter	Method	Standard, Literature
breaking strength (adhesion)	pull-off test	ISO 4624
undermining at scratches	measurement of the width of corrosion across the scratch	ISO 12944-6
water uptake	measurement of changes in dielectric constants by Impedance spectroscopy and calculation of water uptake using the empirical relation by Brasher	[1, 2]
potential	measurement of the potential of the steel/paint interface with the Scanning Kelvinprobe	[3, 4, 5, 6]

Results

The obtained results are shown in Fig. 1 to 7.

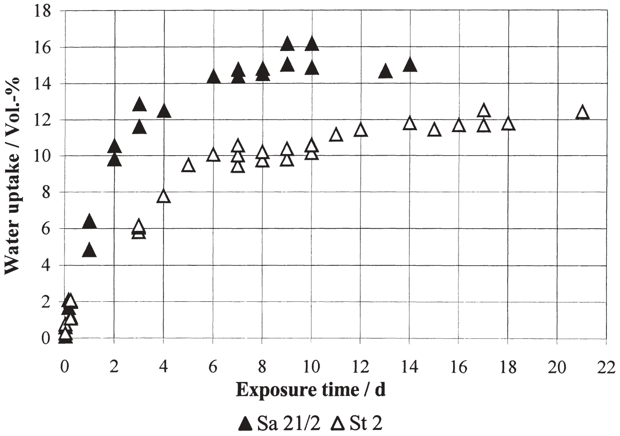

Figure 1. Water uptake of the System No. 1 in a 5 % NaCl solution

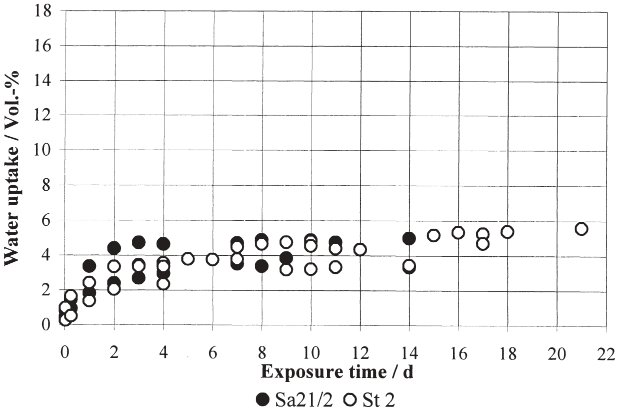

Figure 2. Water uptake of the System No. 2 in a 5 % NaCl solution

The water uptake in the saturated state of the system No.1 (Fig. 1) is 14 Vol.-% and of the system No. 2 (Fig. 2) 4 Vol.-%. In case of system No. 1 it seems to exist a dependence on surface preparation before painting.

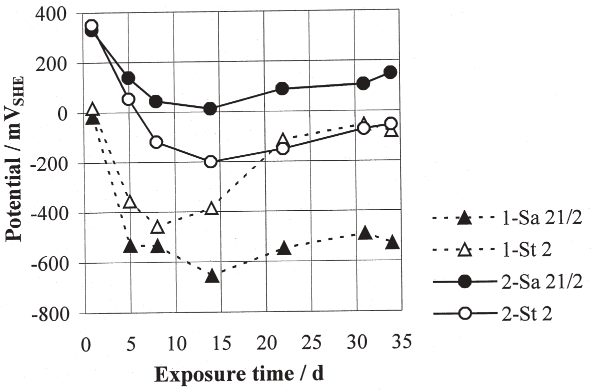

Figure 3. Potential of the steel/paint interface in dependence of the exposure time in humid atmospheres (rF>90 %) measured with the Scanning Kelvinprobe

On blast cleaned steel substrates (Sa $2^1/_2$) the potential (Fig. 3) of

- the coating system No. 1 is close to that of of a free corroding zinc/electrolyt interface,
- the coating system No. 2 is rather positive as the potential of a dry passivated metal surface.

On hand-cleaned (St 2) steel substrates the Fe^{3+}/Fe^{2+}-redox potential was observed for both coatings.

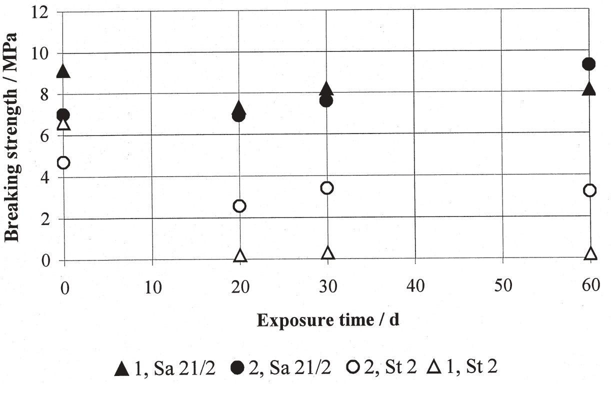

Figure 4. Adhesion of the paint systems exposed to the neutral salt spray test

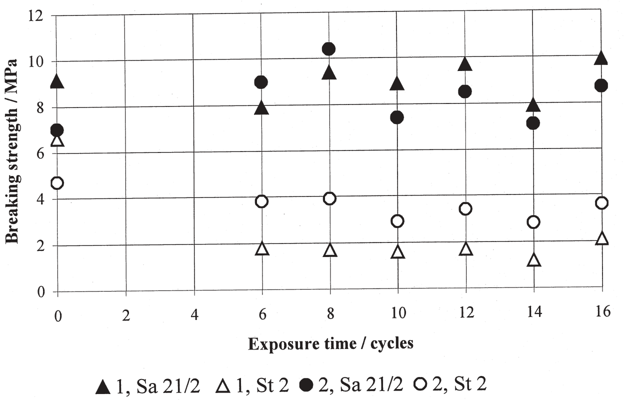

Figure 5. Adhesion of the paint systems exposed to the cyclic alternating test VDA 621-415

The adhesion of the coating systems No. 1 and No. 2 on blast cleaned steel substrates is not affected during the exposition in both tests (Fig. 4 and 5). On hand cleaned steel surfaces the adhesion of both coating systems decrease drastically. The break takes place in the rust layer. In the case of loading by neutral salt spray test the adhesion of coating system No. 1 is completly lost and by cyclic alternating test VDA 621-415 very much reduced. The adhesion of the coating system No. 2 ranges between 3 and 4 MPa in both tests.

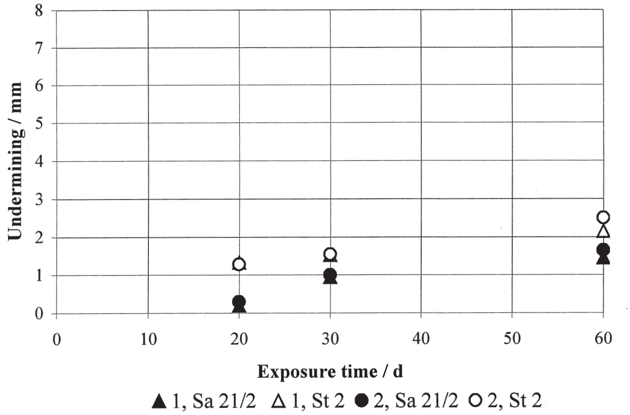

Figure 6. Undermining at scratches of the paint systems exposed to the neutral salt spray test

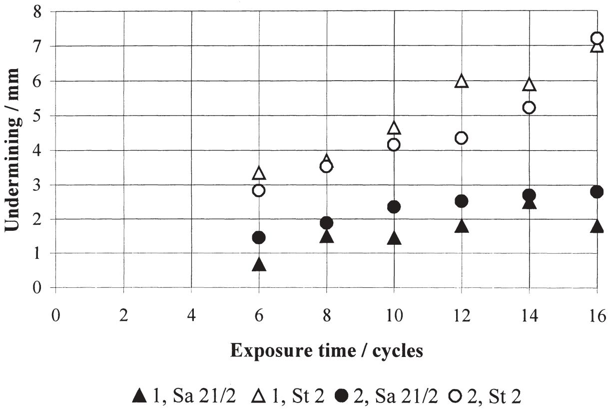

Figure 7. Undermining at scratches of the paint systems exposed to the cyclic alternating test VDA 621-415

The undermining at scratches of the investigated coating systems is higher on rusty then on blast cleaned steel surfaces (Fig: 6 and 7). The differences are more marked in the cyclic alternating test VDA 621-415 than in the neutral salt spray test.

Discussion and Conclusion

On blast cleaned steel substrates the adhesion of the investigated coating systems was not influenced by water uptake of the coatings, even in case of very high water uptake by moisture cured 1-pack polyurethane-coating system. Scratches are especially cathodically protected at their edges by anodic dissolution of zinc as part of the zinc dust primer.

On hand cleaned steel surfaces the rust layer between steel substrate and coating can participate in the corrosion process with rust reduction as cathodic partial reaction. In the presented paper the high water uptake of the moisture cured 1-pack polyurethane coating system enables rust reduction and thus, the change of rust morphology and the loss of adhesion of coating [7, 8]. At scratches rust reduction takes also place at the edge of the defect in form of a cathodic partial reaction which is independent from pigments of the base coating. This reduction is increased by the galvanic cell. In case of cyclic alternating loading reduced rust is reoxidized during dry phases and can participate again in the process during wetting [9, 10]. This is the reason for higher undermining at scratches in the cyclic alternating test (VDA standard 621-415).

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