Progress in Organic Coatings 101 (2016) 186–194

Contents lists available at ScienceDirect

Progress in Organic Coatings

journal homepage: www.elsevier.com/locate/porgcoat

A statistical study into parameter effects on the coverage of organic coatings on rounded steel edges

Andreas W. Momber [a,*], Sascha Buchbach [b], Peter Plagemann [b], T. Marquardt [c]

[a] Muehlhan AG, Schlinckstraße 3, 21107 Hamburg, Germany
[b] Fraunhofer Institute for Manufacturing Technology and Advanced Materials Research (IFAM), Wiener Straße 12, D-28359 Bremen, Germany
[c] Muehlhan AG, Schlinckstraße 3, D-21107 Hamburg, Germany

ARTICLE INFO

Article history:
Received 15 July 2015
Received in revised form 16 May 2016
Accepted 2 August 2016

Keywords:
Coatings
Edge protection
Edge coverage
Rounding

ABSTRACT

The relationships between edge rounding parameters and edge coverage of organic coating systems are systematically investigated. Three organic coating systems for highly corrosive environments are tested. Two edge-geometry related parameters, namely rounding radius (2 levels) and edge rounding process (5 levels), are considered. The edge coverage, as the ratio between dry film thickness at edge and at flat surface, is estimated based on high-resolution microscope inspections on polished cross-sections. The effects are evaluated with a full factorial experimental plan. ANOVA analysis reveals that none of the parameters has a statistically determined effect on the edge coverage. In terms if main effects, rounding process and coating system are more indicative than an edge radius. Larger edge radii do not provide a better edge coverage in general.

1. Introduction

Imperfections on engineering steel constructions are often, although not always, the origin of coating deterioration [1]. Three types of imperfections are known: (i) weld seams, (ii) edges, (iii) other imperfections [2]. This investigation deals with edges, particularly with so-called free edges. As illustrated in Fig. 1, this type of edges covers considerable parts of engineering constructions. Corrosion protection practice shows that coating deterioration starts favourably on free edges. Evidence is provided in Fig. 1c and in Fig. 1d. The reason for this particular behaviour is not completely known. It is frequently assumed that the film thickness of organic coating systems reduces over sharp edges. This may be caused by the surface tension of the liquefied coating film which promotes drop formation over sharp-edge objects [3]. An alternative approach was introduced more recently in Ref. [4]. Based in EIS (electrochemical impedance spectroscopy) investigations, the authors found that coating failure over edges occurred suddenly and not always at the location with the lowest dry film thickness. They concluded that internal stresses in the coating lead to localized cracking in the coating. These localized cracks define the starting point for corrosion. Therefore, dry film thickness may not be the only governing parameter. Other effects, namely coating deformability, may be equally.

In terms of edge preparation, three preparation grades, P1–P3, can be distinguished [2]. Areas exposed to high corrosivity are believed to require rather high-quality cut edges. A criterion for a quantitative assessment is the edge (or rounding) radius R, provided in mm. The definition for the edge radius is illustrated in Fig. 2a. The quality of an edge increases if the value for R increases; R = 0 corresponds to an untreated edge. It is often assumed that a larger edge radius contributes to a better coating coverage as well as to a better corrosion protection performance. Numerous standards call for large edge rounding radii [5–10]. However, there is no investigation known that would provide a statistically sound justification for this requirement.

Chung et al. [11] investigated effects of edge radius and coating composition on edge coverage. Although they achieved higher edge coverage values with an increase in edge radius, they concluded that the effects of coating materials are of equal importance. The utilisation of high-solid paints (80%) reduced edge coverage at equal rounding radius compared to a system with lower solid content (60%). This latter result was approved in [12,13]. Their results also showed that edge coverage was almost independent of edge treatment quality if the coating thickness exceeded 250 μm. Edge retentive coating types were considered in Ref. [3]. The authors recommended the use of 100% solid polyurethane. Osawa et al. [14] achieved very good edge coverage with a coating which contained ferromagnetic pigments. They also found that edge coverage increased if bevel angle decreased. Osawa et al. [15] investigated the

* Corresponding author.
E-mail addresses: momber@muehlhan.com, andreas.momber@t-online.de (A.W. Momber).

http://dx.doi.org/10.1016/j.porgcoat.2016.08.003
0300-9440/

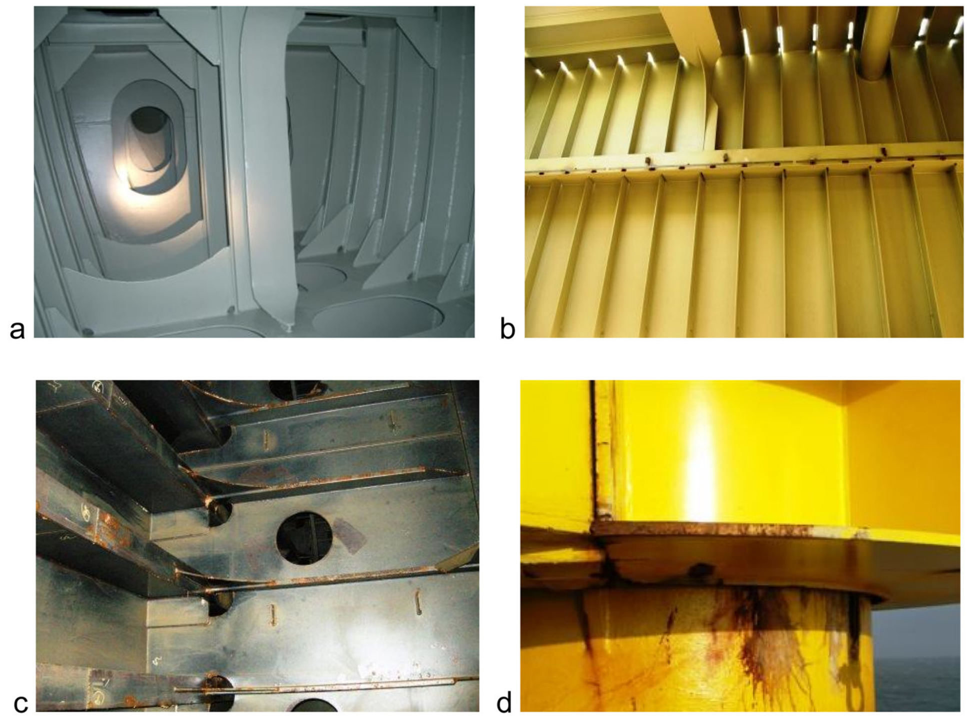

Fig. 1. Free edges on engineering steel structures.
A – Water ballast tank; b – Tank deck with stiffeners; c – Corroded edges in a ballast tank;
d – Corroded edge at an offshore wind power transmission platform

edge coverage of organic coatings on thermally (plasma) rounded edges, and they found that the edge coverage (between 0.5 and 0.9) was in the range of edges treated with 3-pass grinding. The importance of controlling the rheology of liquefied paint films is highlighted in Ref. [16]. This reference obtained high edge coverage numbers with electrocoat paint with micro-gel resin. These results highlight the importance of the coating material, rather than that of the edge geometry.

The review delivers different, partly contradictory, results. The effects of important geometrical and process parameters of the edge rounding process on edge coverage are not investigated in a systematic way. The objective of this paper is the systematic statistical investigation of parameter effects on the coverage capacity of coating systems over edges. These effects include the following: rounding process, coating type, and edge radius.

2. Experimental methods and test procedures

2.1. Film thickness measurements and edge coverage

Dry film thickness (DFT) is believed to be a critical parameter in terms of the corrosion protection at edges. Because the measurement of DFT at edges is not possible with standard DFT gauges, dry film thickness measurements were performed based on microscopic inspections of polished cross sections. The measuring procedure is illustrated in Fig. 2. Selected samples were sliced, and the cross sections of the slices were polished. The measurement of the coating thickness was performed with an optical microscope at a magnification of 100×. The lowest film thickness measured at the edge section was denoted DFT_{Edge}. The assessment criterion, and target parameter for the statistical investigations, was *edge coverage*. This parameter was originally suggested in Ref. [11] as follows:

$$EC = \frac{DFT_{Edge}}{DFT_{Area}} \quad (1)$$

Table 1
Coating systems used for the experimental investigations.

Parameter	System 1[a]	System 2	System 3
Compounds	2	2	2
Base	Epoxy	Epoxy	Epoxy
Hardener	Amine	Amine	Polyamide
Mixing ratio[b]	3.4: 1	2.5: 1	4: 1
Solid content (wt.%)	100	60	69
Density (kg/dm^3)	1.4	1.2	1.4

[a] Edge-retentive system.
[b] Volume percentage.

The parameters DFT_{Edge} and DFT_{Area} are illustrated in Fig. 2a. The ideal case would be EC = 1. This parameter is comparable to the *edge retention percentage* according to Ref. [17]. However, it is modified in such a way that DFT_{Edge} is the lowest DFT measured over the edge section.

2.2. Test samples and coating materials

Substrate material was a standard construction steel with a plate thickness of 10 mm. After cutting, edge rounding with different preparation processes was performed. The rounding processes included the following: mechanical milling (M), grinding (G), plasma beam (PB), solid-state laser (SL), and CO_2 laser (CL). All samples were degreased after rounding, and surface preparation was done by blast cleaning with steel grit H40. The surface preparation standard was Sa 2½ [18]. Fine cleaning was performed in order to remove dust and blasting debris. The surface profile was measured with a mechanical stylus instrument. The readings were between Rz = 50 and 60 µm. Salt readings were also done; the results were between 10 and 18 mg/m^2. The coating application process consisted of two stripe coats (at the edges) and two full coats (at edges and flat areas). Three different coating materials were applied. Their parameters are listed in Table 1. Two coating