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Effects of edge treatment parameters on the protection performance of organic coating systems in a wave chamber

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ABSTRACT

Based on a specially designed accelerated wave chamber ageing tests, the corrosion protection capability of organic coatings over cut edges is investigated. The edges are rounded with different tools, including CO_2-laser, solid-state laser, plasma beam, grinding and milling tools. Two coating systems for ballast water tank environments and two rounding radii are considered. The samples are placed on four locations in the wave chamber, characterized through different corrosive environments. DOE (Design of Experiments) and ANOVA (Analysis of Variance) are used to rank the parameter effects. It is shown that edge radius has no statistically significant effect on the corrosion protection performance of the coatings. In contrast, rounding process and chamber location are extremely significant. A hypothesis of a hierarchic geometrical edge structure is proposed.

1. Introduction

Imperfections on steel constructions are usually the origin of coating deterioration and steel corrosion. Three types of imperfections are known: (i) weld seams, (ii) edges, (iii) other imperfections [1]. 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 reveals that coating deterioration starts very often, although not always, on free edges. An example is provided in Fig. 2, which illustrates the situation in a ballast water tank. The coating is intact at the plane areas, but it deteriorates over free edges. Steel starts to corrode at the arrowed locations due to reduced corrosion protection performance of the coating system. The reason for this particular behaviour is not completely known. A popular hypothesis is that the film thickness of organic coating systems reduces over sharp edges [2]. In a newly formed film, a decrease in film thickness at the edge can be caused by the surface tension of the film. Solvent evaporation takes place at a much greater rate at the edge of the film, because there is a larger surface area per unit volume of fluid near the edge. As more solvent evaporates, a higher surface tension exists at the edge [2]. In a recent issue of this journal [3], the authors have shown that edge radius does not have a statistically significant effect on the coverage of coatings over steel edges.

Three approaches to improve the corrosion protection performance of organic coatings over edges are known:

(i) Edge preparation (which will be the topic of this paper): this includes the rounding of edges by different methods in order to improve their coverage;
(ii) Stripe coating: this includes the application of additional paint layers to the edges (either before or after the full coat) in order to increase the local dry film thickness;
(iii) Development of edge retentive coatings.

The latter approach is a material issue, while the other two approaches are process issues. The second approach belongs to the coating application process. In practice, a combination of (i) and (ii) is a prevalent strategy [4–6].

Numerous regulations have set standards for the geometry of edges. Examples are provided in Tables 1 and 2. It can be recognised from Table 1 that the desired levels of edge treatment depend on corrosivity. Areas which are exposed to a high corrosivity, namely water ballast tanks or slop tanks, require rather high-quality cut edges. Dry and closed sections, such as void spaces, require less edge treatment. It can also be seen that a 45° edge is considered to deliver a reliable corrosion protection even at high corrosive loads. In terms of edge quality, three preparation grades, P1 to P3, can be distinguished [1]; whereby P3 corresponds to the highest

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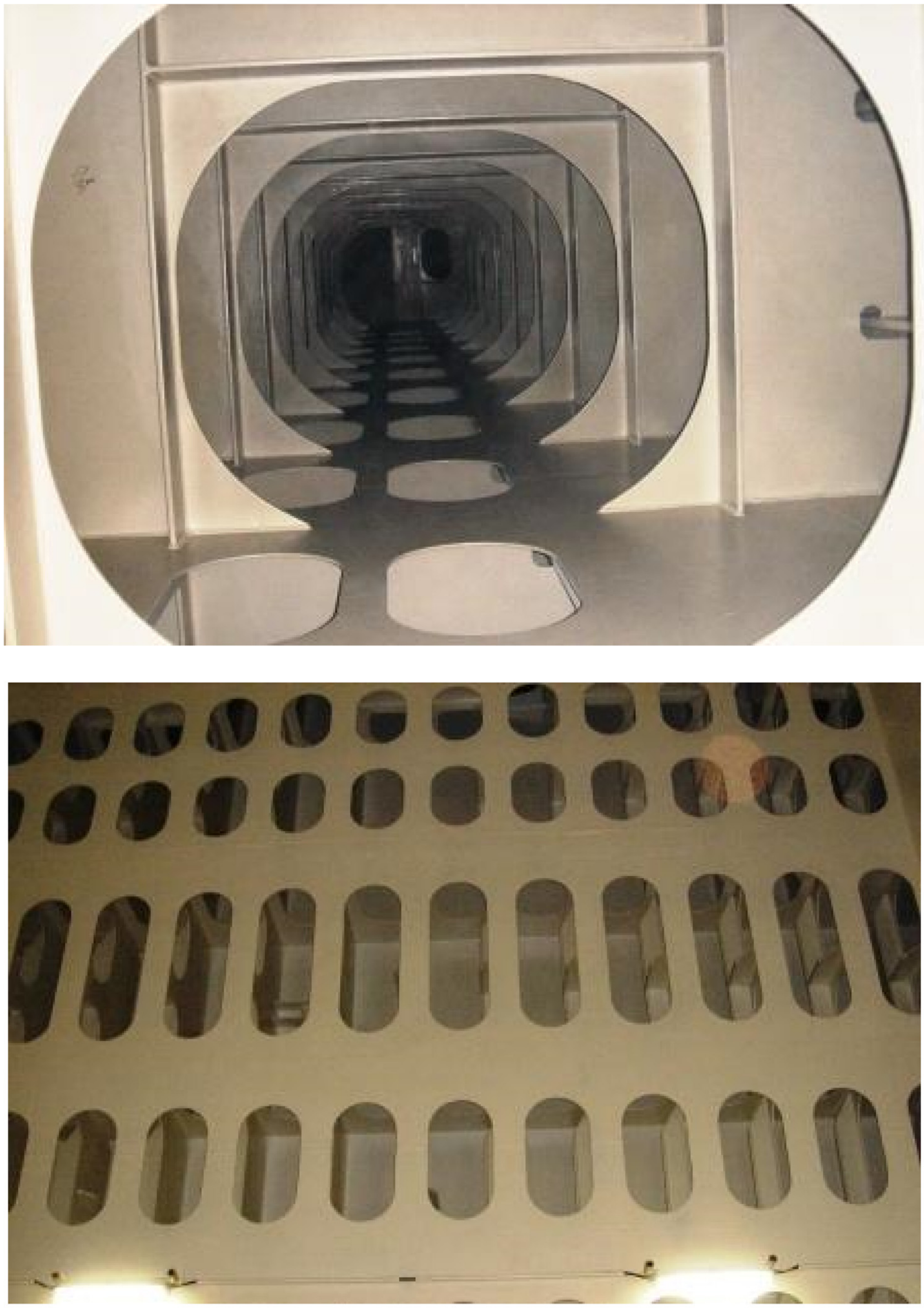

Fig. 1. Examples for free edges in maritime steel constructions.

Table 1
Edge preparation requirements as per German Shipbuilding Standard [7].

Preparation grade	Location/area							
Designation/ description	Void spaces and cofferdams[a]	Crude oil tanks and heavy oil tanks	Ballast water tanks, heeling tanks[b]	Slop tanks, grey water tanks, dirt water tanks[b]	Fresh water and drinking water tanks[b]	Bilges, sumps, pool equipment, etc.[c]	Cargo holds, closed by hatch covers[c]	Cargo holds, open[c]
No treatment	X	X						
Burr removal						X	X	X
Edge grinding (ca. 45°)			X	X	X			

[a] Dry, closed compartments with low corrosivity.
[b] High corrosivity (sea water, heating, temperature gradients, wet-dry cycles, waste water).
[c] Moderate corrosivity (partly exposed to wet environment, partly closed).