Corrosion Resistance of Water-thinnable Paint Systems

Korozní odolnost vodou ředitelných nátěrových systémů

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Abstract

Anticorrosion protection on the basis of water-thinnable paint systems belongs among one of ecological ways of protection of metal parts. The aim of the experiment was to test corrosion resistance of water-thinnable systems Eternal antikor speciál V9503 and Colorlak aquarex V2115 in the salt spray environment according to the norm ČSN ISO 9227. Ductility of used paint systems in complience with the norm ČSN EN ISO 1520 will be also tested, it is a test according to Erichsen. At the end of the experiment measurement, the corrosion speed depending on paint coating thickness was analyzed.

Key words: corrosion, water-thinnable system, paint flexibility

Abstrakt

Antikorozní ochrana na bázi vodouředitelných nátěrových systémů patří mezi jednu z ekologických variant ochrany kovových součástí. Cílem experimentu je podrobit vodouředitelné systémy Eternal antikor speciál V9503 a Colorlak aquarex V2115 degradačním procesům zrychlených korozních zkoušek v prostředí solné mlhy dle ČSN ISO 9227. Použité nátěrové systémy budou testovány i na tažnost dle ČSN EN ISO 1520. Jedná se o test dle Erichsena. V závěru experimentálního měření je provedena analýza rychlosti koroze v závislosti na tloušťce antikorozního systému.

Klíčová slova: houževnatost nátěru, koroze, vodouředitelný systém

Introduction

The most common reason of degradation processes in metal constructions is electrochemical corrosion. Anticorrosion protection systems can be divided into two categories: organic and inorganic. Nowadays, the anticorrosion coatings have to fulfill not only the protective criterion but also ecological aspects consisting in decomposability of organic paint systems. Anticorrosion water-thinnable acrylate-dispersion-based systems is one of the ecologically decomposable paint systems and can be used in low aggressive environments. However, it is a technology with a limited protection of metal parts (Bartoníček, 1980, Dillinger, 2007), which can be used for exchangable machine parts with a huge abrasive wear. Limited anticorrosion protection is also used in protection of soil-processing agricultural machines; this protection is mostly used for parts which have been renovated after abrassive wear (Čičo, et al., 2011; Tolnai, et al, 2002; Kotus, et al., 2010). Water-thinnable paint systems perform a good adhesion to base material and an excellent ductility of the coating itself. Nevertheless, the main criterion is roughness of machined surface. Trethewey, et al. (1995) state the roughness *Ra* of this system 3–12 µm. The goal in the engineering production is to optimalize the production (cutting speeds, cutting liquids) with minimal roughness (Kotus, et al., 2002; Žitňanský, et al., 2012), which however results in a bad adhesion of anticorrosion coatings.

Material and Methods

Anticorrosion systems were applied on steel sheets sized 165×60×1 mm. Steel S235JRG1 was used as a base material. The paint system was applied to the base material by air spraying in two, three or four layers, the break between the individual layer applications was at least 24 hours; the environment temperature was 22 °C. In order to achieve a good drying of the previous layer, a longer time interval of spraying was used (Svoboda, 1985).

Resistance of a paint coating was tested according to Erichsen (ČSN EN ISO 1520), this test was processed also during the corrosion degradation tests, reason for which was to observe degradation of elastic characteristics of the paint systems during corrosion test in salt-spray environment. Test according to Erichsen is based on pressing a steel ball to a sample. There was observed the dependence of depth of the imprint on crack origin in the anticorrosion coating. This test was processed on the group of samples before and during the corrosion degradation test.

As corrosion of water-thinnable paint systems causes untercorrosion of the anticorrosion system itself, there was measured also the surface of some blisters until the red corrosion appeared.

Corrosion resistance of the individual systems was tested in accelerated tests in the salt spray environment in compliance with the norm ČSN ISO 9227. Salt spray is an aggressive environment which simulates enormous load of tested samples.

Results and discussion

Nondestructive method of measuring coating thickness

Thickness of the applied coating was measured by a nondestructive method using a thickness meter Elcometer 456 and a ferromagnetic probe. The goal of the measurement was to analyze coating thickness, where the minimal coating thickness was 80 µm and 150 µm of both anticorrosion systems. Thickness of the coatings was measured on the group of 10 samples after a final application of anticorrosion systems. Afterwards, these samples were used for further analyses of degradation and corrosion impacts. Measured values of applied anticorrosion film thickness are recorded in Table 1.

Table 1: Thickness of applied anticorrosion coating

Anticorrosion coating	Measurements of anticorrosion coating					Average value [µm]
	No. 1 [µm]	No. 2 [µm]	No. 3 [µm]	No. 4 [µm]	No. 5 [µm]	
Eternal antikor upto 80 µm	75.3	70.2	81.2	76.1	73.4	75.24
Eternal antikor upto 150 µm	132.5	145.6	155.1	149.3	143.9	145.28
Colorlak aquarex upto 80 µm	82.3	79.2	74.2	76.1	79.2	78.20
Colorlak aquarex upto 150 µm	149.2	146.9	148.9	142.3	147.3	146.92

Anticorrosion system was applied using the air spraying method. The number of spray-applications was set according to an experimental analysis. For the anticorrosion film upto 80 µm three spray applications were needed and for the anticorrosion film upto 150 µm thickness the spray was applied five times.

Ductility of the paint system according to ČSN EN ISO 1520

This test analyses elastic characteristics of the whole paint system. The principle of the test is pressing a hemispherical casing into a sample which results in to a hemisphere-shaped deformation of outside side of the sample.

Test parameters:

- pressing casing has a hemispherical shape with a diameter of 20 mm,
- deviation from the matrix axis is maximally 0.1 mm,
- pressing is processed with a constant speed of 0.1–0.3 m/s,
- the cup is measured with the accuracy of 0.1 mm.

Cracks in the tested samples were observed at a 10-time magnification. Figure 1 depicts a spherical top after pressing a testing casing.


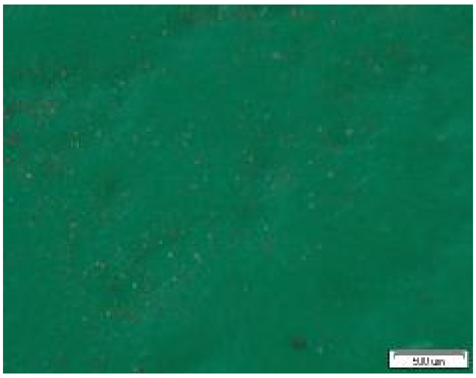

Figure 1: Deformation of tested samples with the cup depth of 5 mm, coating thickness upto 80 µm: Eternal (left) and Colorlak (right)

As it is apparent from Figure 1, anticorrosion system Colorlak performs better elastic characteristics than the Eternal paint system. Table 2 shows values of elasticity of both paint systems before corrosion test.

Table 2: Prolonging values before the origin of a first crack (before corrosion test)

Anticorrosion system	Measurement of values of a spherical top					Average value [mm]
	No. 1 [mm]	No. 2 [mm]	No. 3 [mm]	No. 4 [mm]	No. 5 [mm]	
Eternal antikor upto 80 µm	3.9	4.0	3.8	3.9	4.5	4.02
Eternal antikor upto 150 µm	5.2	5.5	5.0	5.1	5.2	5.20
Colorlak aquarex upto 80 µm	5.8	5.9	5.8	5.6	5.9	5.80
Colorlak aquarex upto 150 µm	-	-	-	-	-	-

Based on the test processed it can be stated that the anticorrosion systems show an excellent elasticity. However, samples with upto 150 µm of thick paint coating Colorlak were destroyed in their metal base. From this reason, no values can be put to the Table 2.

Table 3: Prolonging values before the origin of a first crack (3-day corrosion test)

Anticorrosion system	Measurement of values of a spherical top					Average value [mm]
	No. 1 [mm]	No. 2 [mm]	No. 3 [mm]	No. 4 [mm]	No. 5 [mm]	
Eternal antikor upto 80 µm	4.1	3.8	3.8	4.0	4.0	3.94
Eternal antikor upto 150 µm	5.1	5.2	4.8	4.9	5.0	5.00
Colorlak aquarex upto 80 µm	5.5	5.4	5.6	5.2	5.4	5.42
Colorlak aquarex upto 150 µm	-	5.9	-	-	-	-

Table 3 shows values of cupping values of samples after 3 days under corrosion test in the salt spray environment. A minimal effect on elasticity is apparent from the values in the table. First signals of red corrosion begin to appear.

Table 4: Prolonging values before the origin of a first crack (5-day corrosion test)

Anticorrosion system	Measurement of values of a spherical top					Average value [mm]
	No. 1 [mm]	No. 2 [mm]	No. 3 [mm]	No. 4 [mm]	No. 5 [mm]	
Eternal antikor upto 80 µm	-	-	-	-	-	-
Eternal antikor upto 150 µm	4.9	4.8	4.8	5.0	4.9	4.88
Colorlak aquarex upto 80 µm	5.0	5.1	4.9	5.2	5.1	5.06
Colorlak aquarex upto 150 µm	-	-	-	-	-	-

Due to a large corrosion attack (3 mm blisters) of samples with Eternal coating upto 80 µm, the test could not be processed. According to other measured values (see Table 4) it can be stated that tested anticorrosion coatings perform a good elasticity. The disadvantage of these anticorrosion coatings is a high speed of corrosion degradation.

Origin of blisters during the salt spray exposition

During the corrosion test, there was observed a type of corrosion attack. Both samples showed signs of undercorrosion and origin of blisters; see Figure 2. Degradation process was accelerated by delaminating the anticorrosion coating. This negative aspect finally results in a total surface corrosion. Pitting corrosion of the individual samples, which would interfere into inside structural phases of the steel, was not confirmed. The risk of pitting corrosion appears mostly at noble anticorrosion steels (Hryniewicz, et al., 2012).

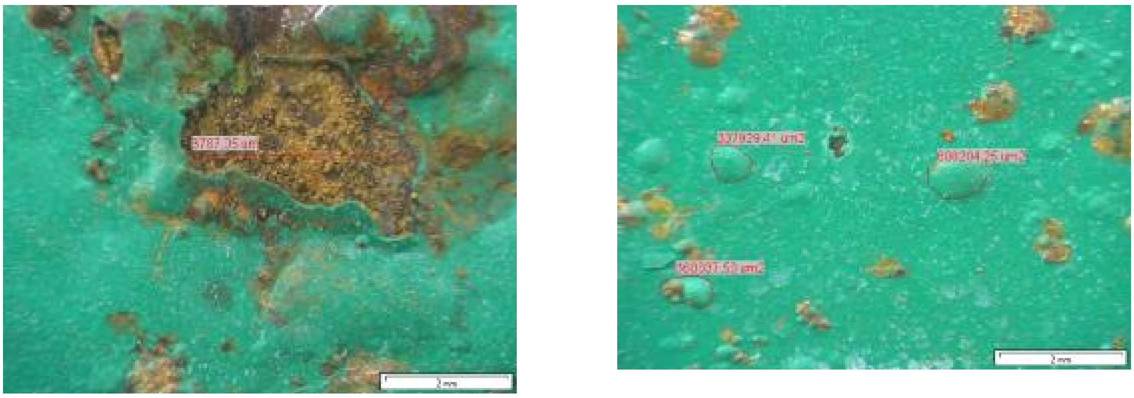

Figure 2: Undercorrosion of Colorlak paint (coating upto 80 µm)

Figure 2 depicts blister surfaces of samples protected by an upto 80 µm thick Colorlak paint after a 5- and 10-day exposition to the salt spray environment. Red corrosion which appears also beyond blisters themselves shows a high coating porosity.

Evaluation of corrosion resistance of used coatings

Corrosion resistance of the individual anticorrosion water-thinnable coatings was tested in compliance with the procedures described in the norm ČSN ISO 9227 – Salt spray test (NSS method). As water-thinnable paint systems are less corrosion resistant, this method is appropriate mostly because of the analysis of pores and inhomogenities of the anticorrosion system. Salt spray chamber Liebisch type S400M-TR was used for this experiment.

Parameters of the test:

- temperature in the salt-spray chamber 35 ± 2 °C,
- concentration of the sodium chloride in a spraying medium 50 ± 5 g/l,
- pH value of the salt solution 6,5–7,2,
- the time interval was set for 1, 2, 3, 5, 10, 15 and 20 days. Based on an every-day visual evaluation and depending on the speed of corrosion degradation, the individual intervals may have differed.

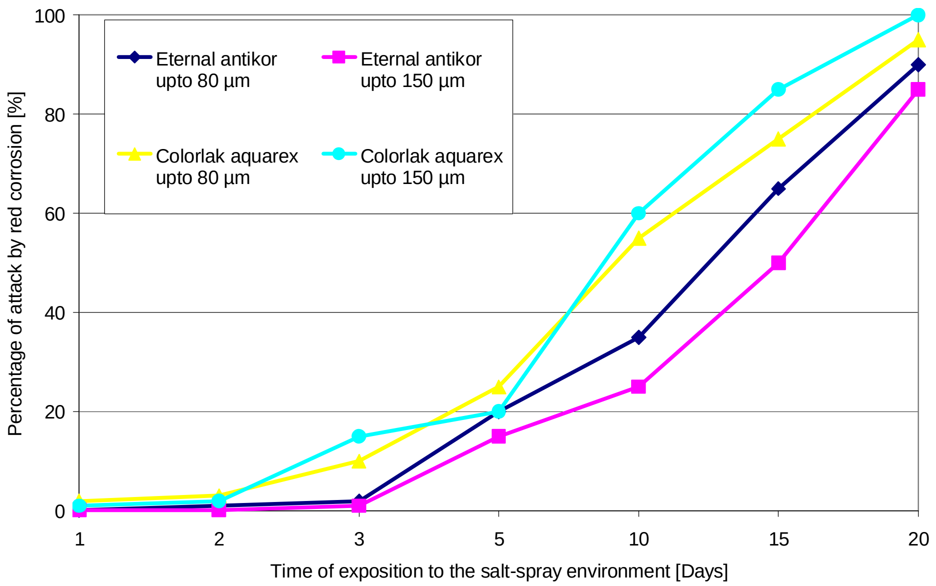

Figure 3: Development of corrosion degradation of the tested samples in given time intervals

As it is apparent from Figure 3, Colorlak has a lower anticorrosion protection than Eternal. There was also proved that a higher coating thickness has a minimal effect on prolonging of coating life. Anticorrosion paint Colorlak with thicker protective coating even performed a more massive corrosion. Acceleration of corrosion process is probably caused by a lower binding ability of the anticorrosion coating with the anchoring profile of tested sample.

Conclusion

Anticorrosion protection of metal parts forms an integral part of engineering production. Current trend is to use water-thinnable paints because of their better decomposability and a lower environmental damage.

However, these anticorrosion coatings are not due to their chemical composition able to resist to a high corrosion pressure. According to the test outputs of the standardly used anticorrosion systems Eternal a Colorlak, it is apparent that these systems are appropriate only for a limited anticorrosion protection.

The main advantage of water-thinnable paint systems is their good ductility and flexibility. This aspect was also proved after corrosion test – the protective coating did not get numb. The ductility is lowered at synthetic paint systems, which may also result in peeling of the protective coating after a longer corrosion stress.

The disadvantage of the water-thinnable anticorrosion systems is undercorrosion of the coating and origin of blisters. There was observed a high degradation speed, which means a lower resistance of the coating to air humidity.

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