Materials Research Proceedings **5** (2018) 225-230 doi: http://dx.doi.org/10.21741/9781945291814-40

Properties of BO100-AGR Clearcoat Anti-Graffiti Coating Systems used in the Railway Industry

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Keywords: Anti-Graffiti Coatings, Free Surface Energy, Rail, Anti-Graffiti Corrosion

Abstract. The paper presents tests results of the selected properties of anti-graffiti paint system for rolling stock industry. The system consists of high solid corrosion protection primer, putty, filler, basecoat and anti-graffiti clearcoat. The results of the research focus on the analysis of corrosion resistance and free surface energy of anti-graffiti clearcoat.

Introduction

In the globalization era, companies' competitiveness is improved by manufacturing processes, focusing attention on new technologies. The fact that the introduction of new products is usually accompanied by the use of new high-strength materials leads to a significant increase in the demand for unconventional, high-performance machining processes using a concentrated energy beam [1-5]. In addition to the optimization of already known and used processes, the effects are consistently implemented by new technologies and materials [6-9].

We are currently observing the development of paint coatings used in various industries [10- 12].

Application of various types of paints (graffiti) on a vehicle may lead to shortening durability of the coating surface. Spray paints should be treated as dangerous substances for coatings because they contain various solvents and other substances that might soften or migrate into protective coating and cause delamination of the coating system. The study of wettability and free surface energy is of great practical importance in industrial processes, especially for paints with special properties like anti-graffiti for rolling stock industry. The paper presents results of free surface energy for anti-graffiti BO100-AGR coating developed in the laboratory of Barwa Company.

To minimize the corrosion problem, the industry uses anticorrosion systems which allow a vehicle to operate without any repairs until the planned term. At the next stage of the study, measurements of the corrosion resistance of the anti-graffiti coating system were performed. Potentiodynamic studies were performed in the water solution of Na_2SO_4 and NaOH at 25^{o}C.

At the end, roughness measurement of the coating system was performed. A test was made to determine the influence of roughness to adhesion properties.

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Materials

Coatings were applied with a SATA spray gun on S355 carbon steel and before the application the surface of steel was polished with 80-grit sandpaper. A coating system consisting of the following layers: anti-corrosion epoxy primer, putty, filler, basecoat and an anti-graffiti BO100-AGR clearcoat. Each layer is applied and dried in accordance with the requirements of technological cards. The prepared samples were conditioned at 23 °C and 50 % humidity for minimum 14 days in order to perform tests on dry coating.

Measurement of contact angle and free surface energy

The value of free surface energy of the construction materials is determined indirectly by measuring the contact angles of the selected measuring fluids. Distilled water and diododomethane (DIM) are used to measure the contact angle. A stereoscopic microscope with a camera and a MicroScan v 1.3 software were used for droplet observation and contact angle measurement. The following values of free surface energy constants of the measuring fluids and their polar and dispersion components were assumed as follows: γ_w=72.8 [mJ/m^2], $\gamma^p{}_w$=51.0 [mJ/m^2], $\gamma^d{}_w$=21.8 [mJ/m^2], γ_d=50.8 [mJ/m^2], $\gamma^p{}_d$=2.3 [mJ/m^2], $\gamma^d{}_d$=48.5 [mJ/m^2]. The measuring liquid was applied to the test surface with a 5 µl constant volume micropipette.

a) b)

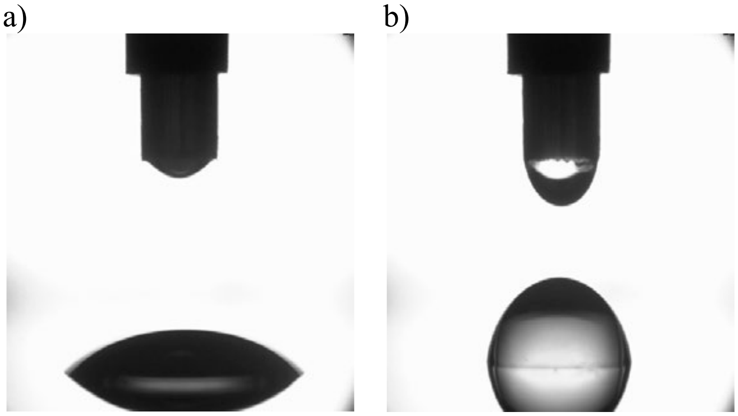

Fig. 1. View of measurement of the contact angle of diododomethane (a) and of distilled water (b)

Free surface energy (FSE) values were determined by measuring the contact angle. The FSE estimation was done at least six times for each surface. Table 5 summarizes the averaged wetting angle and free surface energy measurements of the BO100-AGR anti-graffiti coating systems. Analyzing the obtained results, we can observe high repeatability of the measurements, as evidenced by small values of standard deviations (Table 1).

One of the most commonly used methods for determining free surface energy is the Owens-Wendt method in which it is assumed that the free surface energy is the sum of two components, dispersion and polar:

$$\gamma_s = \gamma_s^d + \gamma_s^p \tag{1}$$

where:

$\gamma^d{}_S$ - *d*ispersion component of free surface energy,
$\gamma^p{}_S$ - polar component of free surface energy.

Table 1. Results of contact angle measurements and free surface energy of the BO100-AGR anti-graffiti coating systems

Measuring series number	Average angle - water	Average angle - DIM	E_p [mJ/m^2]	γ^d [mJ/m^2]	γ^p [mJ/m^2]
1	78.4	40.2	49.2	40.1	9.1
2	80.3	40.0	48.5	40.3	8.3
3	80.9	40.5	48.0	39.9	8.1
4	83.6	39.7	47.2	40.3	6.9
5	79.8	41.1	48.3	39.7	8.6
6	80.8	41.4	47.7	39.5	8.2
arithmetic average	80.63	40.48	48.15	39.97	8.20
standard deviation	1.71	0.66	0.69	0.33	0.73

Corrosion resistance tests

Corrosion resistance examinations were carried out by means of potentiodynamic methods using an Autolab PGSTAT100 potentiostat/galwanostat with the FRA2 module, in non-deaerated solution at 25 °C, which consisted of the following:

- 0.1M Na_2SO_4
- 0.1M NaOH

Prior to electrochemical studies, the samples were exposed to a corrosive solution in current-free conditions for 120 minutes. Potentiodynamic test were conducted in a three-electrode setup: the test electrode; reference electrode (saturated calomel electrode (SCE)); auxiliary electrode (platinum), up to the potential of 1800 mV, or to the current above 1mA/cm^2. The test material was polarized with a potential sweep rate of 0,2 mV/s. After the tests (after 24h), potentialadynamic tests were repeated. The extension "corrosion2" has been added to the names of the samples.

In both studied solution coating systems through it protective properties lower corrosion current, increasing corrosion resistance and vehicle lifetime. Also, the isolation steel from the electrolyte causes increasing polarity resistance. The results are shown in Tables 1 and 2 and also in Fig. 1 and Fig. 2.

Table 2. Results of electrochemical studies, potentiodynamic test conducted in 0.1M Na_2SO_4

Na_2SO_4	Rt [kΩcm^2]	E_{kor} [mV]	I_{kor} [µA/cm^2]
Steel	2.39	-735	7.80
Corrosion	798	-765	0.017
Corrosion 2	343	-730	0.038

Table 3. Results of electrochemical studies, potentiodynamic test conducted in 0.1M NaOH

NaOH	Rt [kΩcm^2]	E_{kor} [mV]	I_{kor} [µA/cm^2]
Steel	62.2	-350	0.523
Corrosion	5330	-305	0.0056
Corrosion 2	129800	-180	0.00019

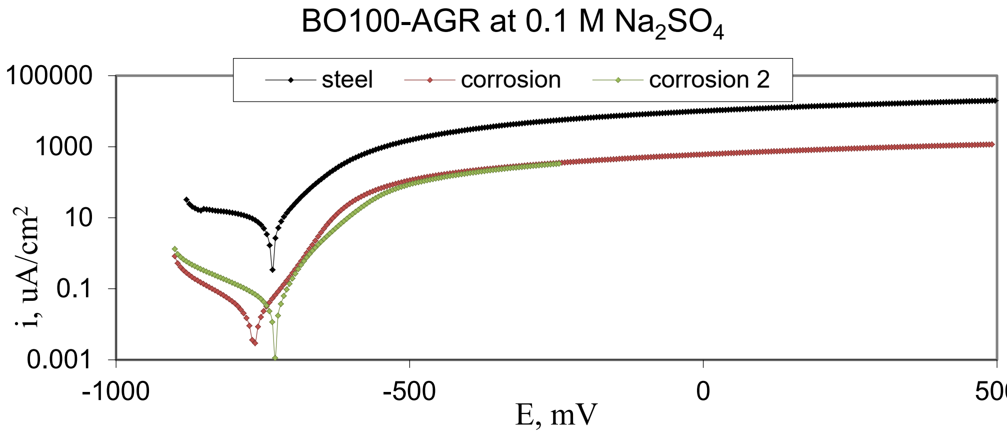

Fig. 2. Steel polarization curve with the BO100-AGR coating system in 0.1 M Na_2SO_4 solution

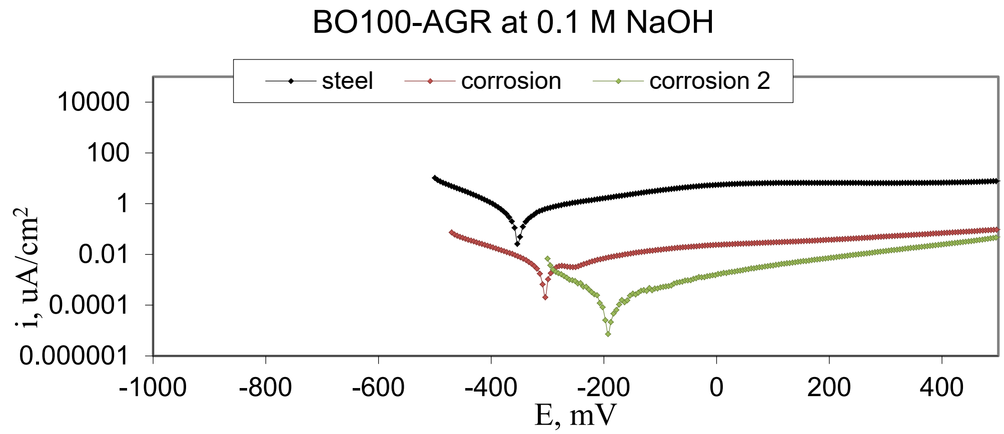

Fig. 3. Steel polarization curve with the BO100-AGR coating system in 0.1 M NaOH solution

Roughness measurements

The roughness of the BO100-AGR anti-graffiti coating systems was measured at the Laboratory for Measurement of Geometric Quantities of the Kielce University of Technology using TALYSURF CCI equipment.

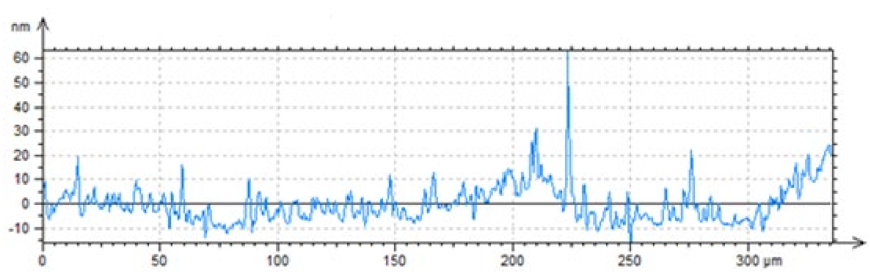

Fig. 4. View of roughness profile of the BO100-AGR anti-graffiti clearcoat

The roughness was measured in two directions perpendicular to each other. Then, the following average value was calculated: Ra = 3.92÷4.04 nm. Samples of S355 steel after grinding with P80 abrasive paper, on which coatings were applied, had roughness from 0.74 to 0.79 µm.

Fig. 4 presents an example of two-dimensional surface microgeometry measurement of the BO100-AGR anti-graffiti coating system. Table 4 presents the most important average roughness parameters of the tested coating system. The low value of roughness parameters also has influence on adhesion properties.

Table 4. Results of roughness profile according to ISO 4287

Parameters of roughness	Anti-graffiti coating system
Rp [nm]	37.21
Rv [nm]	9.20
Rz [nm]	46.42
Rc [nm]	16.36
Rt [nm]	71.37
Ra [nm]	3.98
Rq [nm]	5.70
Rsk	2.08
Rku	12.94

Summary

The study revealed that BO100-AGR anti-graffiti coating systems are characterized by low value of free surface energy and BO100-AGR anti-adhesive properties can be significant in potential applications on rail vehicles. Possible further research, with deeper investigation on the impact of particular factors, should include statistical multivariate analyzes [13, 14], including CA (cluster analysis) [15, 16] and PCA (principal components analysis) [17, 18], as well as alternative – in relation to probabilistic – uncertainty of results e.g. fuzzy approach [19, 20]. It may also be interesting to compare subjective and objective – by means of image analysis methods [21-25] – visual assessments of protected surfaces.

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