TECHNOLOGY AND APPLICATION OF ANTI-GRAFFITI COATING SYSTEMS FOR ROLLING STOCK

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Abstract

The article describes the technology and application of anti-graffiti coating systems for rolling stock, i.e. coatings resistant to devastation by graffiti-vandals and easy to be renovated later. Paint systems for rolling stock must fulfill mechanical and qualitative properties to longer maintenance protective and decorative properties on the vehicle. Graffiti 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 and finally lead to shortening durability of the coating surface. Surface free energy is of interest in the field of coating technologies and cleaning procedures, because it is a factor which affects such surface properties and interfacial interactions as adhesion, adsorption and wetting. The contact angle of a liquid on a solid surface is a measure of a free surface energy so the study of wettability and free surface energy is of great practical interest in industrial processes, especially for paints with special properties like anti-graffiti for rolling stock industry. This paper presents results of the investigation on the free surface energy for the anti-graffiti BO100-AGR coating developed in laboratory of Barwa Company. The system consists of high solid corrosion protection primer, putty, filler, basecoat and anti-graffiti clearcoat. The research was based on anticorrosion coatings system with transparent layer with reduced adhesion of each subsequent types of contamination.

Keywords: Anti-graffiti coatings, surface free energy, wettability, rolling stock, rail

1. INTRODUCTION

By applying new engineering materials or protective coatings, it is possible to improve the functional properties of machine parts so that they are resistant to corrosion, abrasion and erosion, and possess high fatigue strength. The new materials, for instance, alloy steels, are usually costly, which is undesirable, because the higher the cost of the material, the higher the price of a finished product. However, if an element is to be subjected to high loads, then strength rather than cost is a primary factor. Applying protective coatings to machine parts is economically justifiable if the wear is local or if the coating material is expected to display properties different from those of the substrate. Most surface layers are technological surface layers (TSLs) - they are produced before objects are used. Functional surface layers (FSLs), on the other hand, are applied during maintenance [1-3] so they are of interest in the field of protection against vandalism.

Currently, anti-graffiti coating systems for rolling stock are experiencing high development dynamics, which have different properties [4]. Graffiti paints, that are difficult to remove, require the use of more aggressive materials, which increase the possibility of mechanical or chemical damage of the coating system and consequently reduce the thickness of the protective coating or remove it completely. In addition, aggressive chemicals removers are dangerous to the users and environment [5].

The article presents the comparative tests results of selected properties of anti-graffiti paint system for rolling stock industry.

2. MATERIALS

Coatings was applied with a SATA spray gun on S355 carbon steel, before the application the surface of steel was polished with 80-grit sandpaper. Coating system consisting of the following layers: anti-corrosion epoxy primer, putty, filler, basecoat and anti-graffiti clearcoat BO100-AGR. Each layer is applied and dried in accordance with the requirements of the 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.

3. RESULTS OF INVESTIGATIONS AND DISCUSSION

3.1. Microstructure

A microstructure analysis was conducted for anti-graffiti coating systems using the JEOL JSM-7100F scanning electron microscope with field emission and the Hirox KH-8700 light microscope.

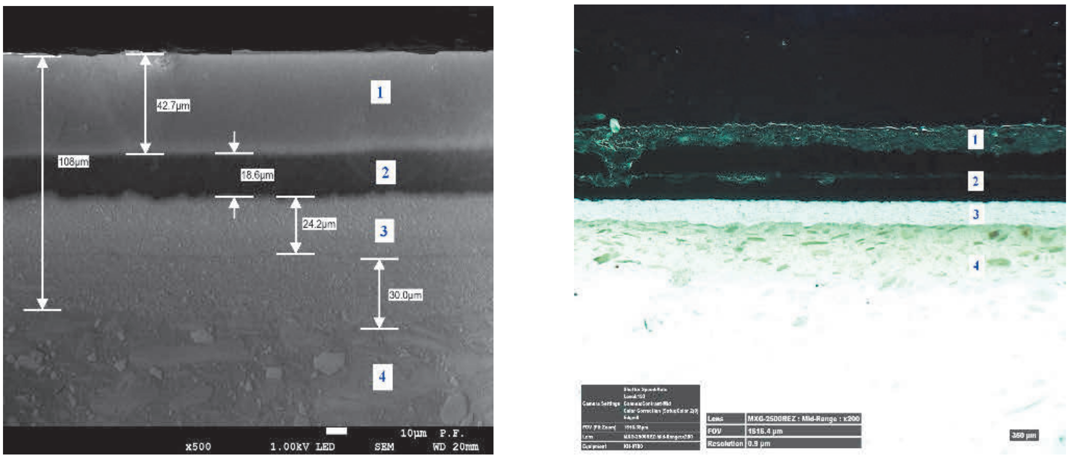

Figure 1 SEM (left) and LM (right) micrographs of the polished cross-section throug a anti-graffiti BO100-AGR coating system on S355 carbon steel substrate: 1- anti-graffiti layer, 2 - base layer, 3 - undercoat layer, 4 - putt

The thickness of the obtained coating systems was from approx. 2350 to approx. 2450 µm. There are clear boundaries between the individual layers (**Figure 1**). **Figure 1** shows the clear boundary between the varnish layers and the putty. Also the varnish layers are free of pores and microcracks.

3.2. Measurement of contact angle and free surface energy

One of the most commonly used methods of determining the contact angle of a material [6] is a method based on the geometry of the droplet (**Figure 2**). The surface of the droplet is most often in the shape of a circular arc, and then the contact angle is calculated from the measurement of the height h and the radius of the contact surface of the drop r. The height of the circular arc is given by h = R (1 - cosΘ) and the surface contact radius r = R sinΘ. From these relationships we get a equation (1):

$$\Theta = \frac{2h}{r} \tag{1}$$

where:

h - height of circular arc,
r - the radius of the contact surface of the drop.

The value of free surface energy of construction materials is determined indirectly by measuring the contact angles of selected measuring fluids. Distilled water and diododomethane (DIM) are used to measure the contact angle. The stereoscopic microscope with the camera and the MicroScan v1.3 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: 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.

Free surface energy (FSE) values were determined by measuring the contact angle. FSE estimation was done at least six times for each surface. **Table 1** 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**).

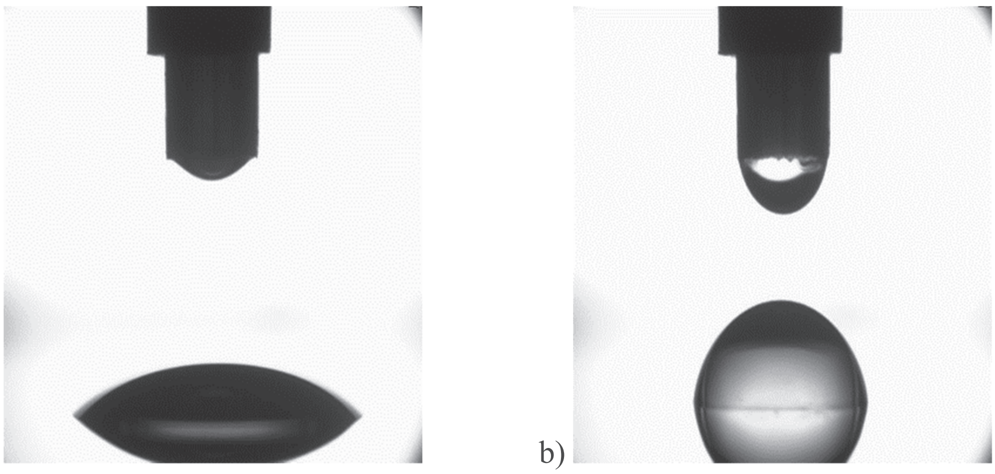

Figure 2 View of measurement of the contact angle of diododomethane (a) and of distilled water (b)

Table 1 Results of contact angle measurements and free surface energy of 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

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:

$$\gamma_s = \gamma_s^d + \gamma_s^p \qquad (2)$$

where:

$\gamma^d{}_S$ - dispersion component of free surface energy,

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

3.3. Measurement of surface geometric structure

Measurements of surface geometric structure were carried out at the Laboratory of Computer Measurements of Geometric Quantities of the Kielce University of Technology. The surface geometric structure (SGS) substantially influences many processes that occur in the outer layer. A lot of publications deal with the measurement methods and the assessment of surface roughness and waviness [7-9]. Tests were performed using a Talysurf CCI optical profilometer using the coherent correlation interferometry method, enabling a resolution of 0.01 nm with a z axis resolution. The measurement result is recorded in a matrix of 1024x1024 measuring points using the x10 lens, giving a measured area of 1.65 mm x 1.65 mm and a horizontal resolution of 1.65 μm x 1.65 μm. Ten measurements were made on samples of anti-graffiti and S355 steel, allowing averaging of the results. The obtained images of surface stereometry and their analysis using the software TalyMap Platinium allowed to evaluate the geometrical structure of the examined surfaces.

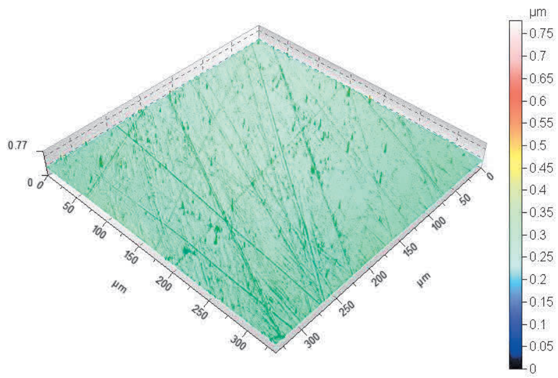

Figure 3 Isometric view of the surface roughness of the anti-graffiti BO100-AGR coating system

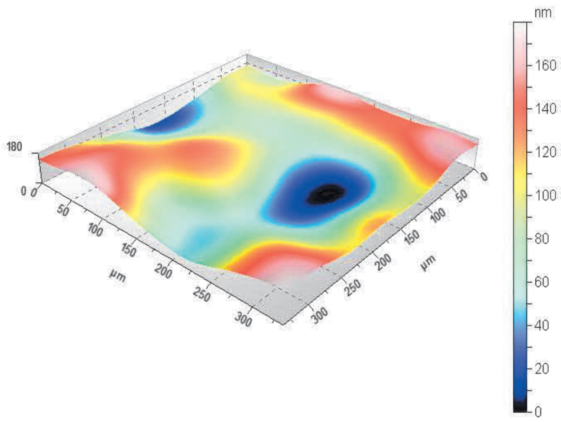

Figure 4 Isometric view of the waviness surface of the anti-graffiti BO100-AGR coating system

Figure 3 shows a sample isometric roughness of the surface of the anti-graffiti BO-100AGR coating system, while **Figure 4** shows the isometric image of the wavy surface of the coating system. **Table 2** summarizes the most important SGS parameters of the tested anti-graffiti coating systems. The tested anti-graffiti coating systems had averaged mean arithmetic surface roughness deviations from the average surface area Sa = 6.6÷26.9 nm. Samples of S355 steel sanded with P80 grain sandpaper on which coatings were applied had Sa = 1 234.5÷1 863.2 nm. Parameter Sa is the basic amplitude parameter for quantifying the state of the surface being analyzed. A similar trend in the measurement of anti-graffiti and S355 coating systems was observed for the quadratic surface roughness Sq, which has a strong correlation with the Sa parameter. As a result of coating application, the surface roughness was significantly reduced.

Table 2 Averaged parameters of the surface geometric structure of anti-graffiti BO-100AGR coating system

SGS parameters	BO100-AGR
Sq (nm)	11.8
Ssk	6.90
Sku	155.9
Sp (nm)	501.9
Sv (nm)	277.8
Sz (nm)	779.6
Sa (nm)	16.8

4. CONCLUSION

- Analyzing the microstructure, it can be concluded that the thickness of anti-graffiti coating systems is in the range of 2300 ÷ 2400 μm. In addition, paint systems are free of pores and microcracks.
- The BO100-AGR is characterized by good anti-adhesive properties and this is related to the roughness of the topcoat. The BO100-AGR anti-adhesie properties can be significant in potential applications on rail vehicles.
- The high values of the slope coefficient of the surface of the Sku (kurtosis) indicate the low dispersion of the ordinate surfaces. The positive values of the asymmetry coefficient of the surface Ssk (skewness) show that making faces with a smooth surface without deep crack.

The obtained results may be useful for users of installations exposed to devastation and thus they are of great economical interest [10-12], which should be included in the decision-making rules [13]. Regardless, obtained results may be useful in other coatings developments [14-18] and this problem create a true challange for a light microscopy [19] and 3D image analysis methods [20,21]. Recognized analytical problems related to microstructures may be also interested in other similar investigations [22-26].

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