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ANTICORROSION COATINGS SYSTEMS FOR RAILWAY INDUSTRY CORROSION PROTECTION

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Abstract

The article is focused on corrosion problems in the rolling stock. Various factors which determine speed intensity of a corrosion process are presented. Such factors include construction materials, geometry, treating these materials, the variability of weather condition and a human factor. Attention is given to provide adequate service to extend corrosion resistance of an entire system. The article presents costs of removing effects of the corrosion. There is also presented an anticorrosion coating system with a transparent layer and reduced adhesion of each subsequent type of contamination which protects system from harmful external factors and allows the corrosion resistance to be extended on the entire system.

Keywords: electrochemical corrosion, corrosion protection, corrosion protection of rolling stock, railway industry

1. INTRODUCTION

Corrosion protection is a complex, multi-task process dependent on many factors. These factors are: materials, materials processing, construction geometry, coatings, human factors and weather conditions. In order to provide the required corrosion resistance a proper selection of construction materials must be provided. By a proper selection we mean using steel with increased corrosion resistance or replacing plastics with metal to selecting protective coatings adequate to the operating conditions. A vehicle should have a geometry that meets required functional properties and allows to use adequate corrosion protection. For this reason sharp edges, semi-enclosed spaces etc should be avoided. An important process at this stage is to prepare the metal surface before paint application to ensure proper expansion of surface area to remove unwanted metal oxides and organic contaminations in the form of fats and oils from the surface. The next stage of protecting objects against corrosion is to choose the proper coating system. It is important to pay attention to an expected durability of the rolling stock, which is counted in tens of years with the possibility of reparation throughout the operation. There are used special systems for industrial applications that fulfills requirements of anticorrosive protection which also meet standards for flammability.
Another important issue is to protect paintings before end users and to ensure a proper operation of the vehicle. Even best designed vehicles and carefully produced but without a proper operation will not be able to function till their predetermined shelf life. Therefore an owner of the rolling stock should follow the manufacturer's instructions because the producer knows what exact materials were used during the production , how to handle with them and what may prolong the life of the product for next years. 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 protective coating and cause delamination of the coating system. 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 the environment.

Losses caused by the corrosion affects not only the manufacturer or the end user. It is an economic problem which affects society and has negative influence on the value of national income. Below are given estimated costs caused by the corrosion damages. These figures are only estimates - it is estimated that in developed countries the percentage of threshold related to the costs caused by the corrosion is approx. 1 to 5% of GDP (1% for Japan (late 20th century), 3.5% - United Kingdom (1970), 4.5% - USA (1975) [4]. For Polish society which is less organized, these costs should be higher. However, if we assume only 5% of GDP, as the cost of corrosion damage and multiply by GDP 2012-2013 [1] it is estimated at some 20 billion dollars per year. Anticorrosion coatings systems can be measured by different methods [2-4].

The amount of losses caused by corrosion includes:

- direct losses - value of the scrapped equipement due to corrosion, construction, equipment, buildings destroyed by the corrosion, as well as the cost of materials and labor required to repair or replace corroded parts and pieces of equipment, structures, etc.
- indirect losses - the cost of shutdowns and production losses, cost of raw materials, spare parts, energy losses, interruptions in energy deliveries, financial results of deterioration of the quality of products, losses of associates, penalties, etc. [5].

The article presents results of mechanical and explotation tests in the laboratory of the coating system containing an anti-graffiti layer BO100-AGR intended for the application on the rolling stock. The work payes attention to the possibility of shortening the stoppage period of the rolling stock and lengthening periods between next repairs. Application of the coating with decreased ahesion shortens the contact time and reduces the contact between the surface area of the painting and hazardous substances. Application of BO100-AGR also aims at facilitating the maintenance of the vehicle by eliminating aggressive paint removers. We are seeing a rapid development of new materials and coatings used in the various fields of science and technology [6-13].

2. MATERIALS AND TREATMENT PARAMETERS

The coating was applied with a SATA spray gun on S235 carbon steel. Before the application the surface of steel was polished with 80-grit sandpaper. The coating system consists of the following layers: anti-corrosion epoxy primer, repair filler, primer 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 degrees Celsius and 50% humidity for minimum 7 days in order to perform tests on the dry coating.

3. RESULTS AND DISCUSSION

The cured coating was also tested for mechanical properties, corrosion and humidity resistance. After the conditioning period had finished, thickness of the dry coating was tested by a magnetic induction method. Adhesion tests were performed by a cross cut method and a pull-off test. Hardness of the cured coating was measured with Koenig pendulum. The corrosion resistance test was performed in a salt spray chamber according to PN-EN ISO 9227 at 35^{o}C using 5% saline solution. The tests in a humidity chamber were conducted according to PN-EN ISO 6270-2 with following parameters of the chamber inside: humidity 100%, temperature 40^{o}C. Summary tests results are presented in Table 1.

Table 1 Selected properties of the dry coating applied on steel

Test	Standard	Result
Cross-cut	PN-EN ISO 2409	Gt0
Adhesiveness [MPa]	PN-EN ISO 4624	3,66
Hardness [s]	PN-EN ISO 1522	171
Flexibility [mm]	PN-EN ISO 6860	42

Measurements of "orange peel" were also made. Which it is responsible for the final appearance of the coating. The measuring device laser beam optically scans the coating surface undulation, like the eyes captures the dark-light pattern reflections. The results are shown in five wavelength ranges from 0.1 to 30 mm Table 2.

Table 2 Orange peel measurement results

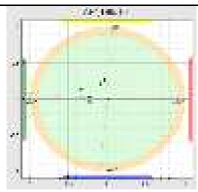
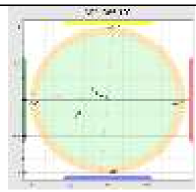
The parameter (corresponding to length of surface undulation)	Range [mm]	Results	Standard deviation
du	0,1 <	17,6	2,2
Wa	0,1 – 0,3	35,0	1,6
Wb	0,3 – 1	62,7	1,4
Wc	1 – 3	40,8	0,6
Wd	3 – 10	26,9	0,4
We	10 – 30	23,8	5,7
LW	1,2 - 12	22,3	1,0
SW	0,3 – 1,2	60,0	0,4
DOI	-	76,9	0,6

The measurements of gloss and color parameters were conducted with Byk micro-Tri-gloss and Minolta Spectrophotometer CM-600d on the samples after removing graffiti from coating surface. The measurements were performed both before the application of graffiti after cleaning with water and additionally after cleaning using solvent nitro. The results are summarized in Table 3. After the test, the sample was dried, and the measurements of gloss and color parameters - L * a * b * for light D65. The results are shown together with diagrams of the color change. The color change is expressed as ΔE, which is defined by the equation (1):

$$\Delta E = \sqrt{(\Delta L^*)^2 - (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (1)$$

Gdzie:
ΔE – color difference expressed as the distance between two points in three-dimensional space,
ΔL* – the difference in distance between two points in the dimension L - brightness,
Δa* – the difference in distance between two points in dimension a - green and red color.
Δb* – the difference in distance between two points in the dimension b - blue and yellow color.

Table 3 Change of color and gloss parameter after cleaning

Sample	Medium	Gloss change	Color change	
1	Water	No loss of gloss	1. ΔE = 0,44 2. ΔE = 032 3. ΔE = 0,61	
2	Nitro solvent	No loss of gloss	1. ΔE = 0,67 2. ΔE = 0,38 3. ΔE = 0,43	

The next test of resistance to aggressive environmental conditions (corrosion and moisture) were finished and assessed after 1000 hours of exposure. The result revealed no changes in the tested coatings (no blistering, cracking, corrosion or thread-like corrosion). Given time of 1000 hours is a minimum for the coating to be resistant to environmental effects (Tables 4 and 5). However, this time could be extended when aluminum is used as a substrate instead of steel.

Table 4 Results after corrosion resistance test

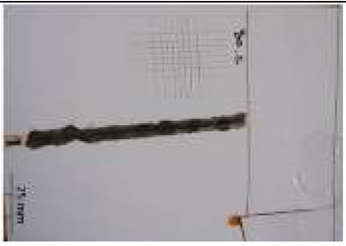
Exposure to salt spray [h]	1000
Resistance to salt spray [h]	> 1000
Degree of blistering	0
Degree of corrosion	0
Degree of exfoliation	0
Degree of cracking	0
Degree of delamination around of crack [mm]	2
Degree of corrosion around of crack [mm]	0,3
View of sample after the test	

Table 5 Results after humidity resistance test

Exposure to moisture [h]	1000
Resistance to moisture [h]	> 1000
Degree of blistering	Random spots 2(S3)
Degree of corrosion	0
Degree of exfoliation	0
Degree of cracking	0
View of sample after the test	

A cleaning test was also conducted. Paint spray was applied to the anti-graffiti coatings. Several different graffiti paint spray were applied on a sample of the BO100-AGR coating system. Such prepared panels were left under both ambient and the sun condition from one hour to 72 hours. After this time test of removing graffiti paint was performed. Removing graffiti from the sample was performed with hot water under pressure in the beginning. Traces of graffiti paint were cleaned with nitro solvent. The process is shown in Figure 1.

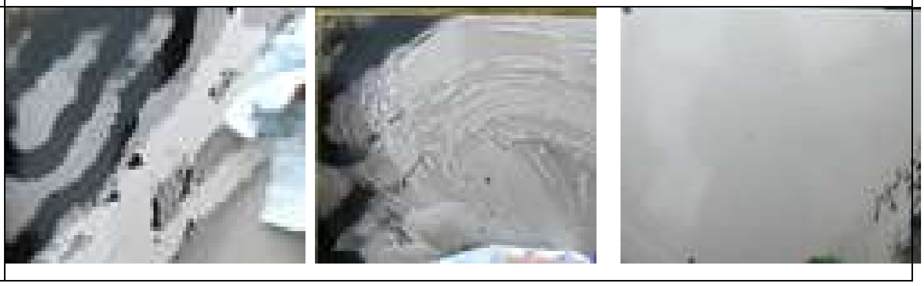
The view of the sample after graffiti aplication. Dry surface.	
Removing the graffiti paint with only hot water under pressure	
The traces of the graffiti paint removed with nitro solvent	

Fig. 1 Steps in removing spray paint from anti-graffiti coatings

The presented anti-graffiti coating system enables the removal of contamination including graffiti paint by using water under pressure. There is no need to use chemicals removers to clean a surface. Any remaining traces of graffiti paint can be removed with a common remover, without damaging the clearcoat layer because the amount of remaining contaminants and the ease of removal do not require a long time of contact with the coating.

Significantly remove of graffiti layer was observed during the cleaning test with pressured water. To completely remove the contamination the surface was wiped off by using fabric soaked with nitro thinner. Restricting the use of chemical cleaners helps to protect the environment.

The use of water under pressure instead of the washing agent reduces the cost of cleaning the surface.

After a cleaning test with water and solvent, there is no change of gloss, and color change of approx. 0.5 is so small that it can result from fluctuation of paint distribution on the sample as well. Note that the human eye sees a color difference when value of ΔE is about 2. The coating after cleaning from graffiti contamination did not show any mechanical damage, they do not seem to change the aesthetic and functional properties.

Examining the surface in terms of orange peel gives satisfactory results (Table 2). The ranges from Wa to We are quantitative illustration of the structure of corrugated surface of a specified size. The smaller the value of Wa-We wave ranges the smoother surface is obtained. In the presented results DOI (distinctiveness of image) parameter has a high value, and the number of waves Wa-Wb at about 35-60 but in relation to the total occurrence of a LW (long wave) is at 22.3 which translates to a slight perception of orange peel on the surface. As a result the coating is characterized by high aesthetic values.

CONCLUSIONS

Speaking of clearcoat anti-graffiti coating means product that gives you the ability to remove unwanted subsequent layers of paint without damaging the original paint layer. Decreased adhesion means that it is easier to remove contamination from the surface of the structure, for example: dust, dirt, acidic or alkaline sludge or graffiti paint, which must also be regarded as an aggressive agent for the coating. Any substance which will be on the paint surface affects its structure, causing irreversible changes in the paint layer, as far as its complete destruction and reveal the not resistant basecoat. This may lead to a situation when it will be necessary to renovate ahead of the schedule, resulting in waste of: time, labor costs of employees, the installation cost (fans, heating), the cost of paint. It is reasonable to use of clearcoat that will possible best secure the system against external influences.

REFERENCES

[1] CENTRAL STATISTICAL OFFICE, Information Note, Warsaw 2014,.

[2] RADZISZEWSKI L., The influence of the surface load exerted by a piezoelectric contact sensor on testing results: Part I, The displacement field in the solid, Arch. of Acoustics, Vol. 28, 2003, pp. 71-91.

[3] RADZISZEWSKI L., The influence of the surface load exerted by a piezoelectric contact sensor on testing results: Part II, The electrical transients generated by piezoelectric sensor, Arch. of Acoustics Vol. 28, pp. 93-100.

[4] RADZISZEWSKI L., Intrusive effect of a contact transducer on testing results, Metrology and Measurement Systems, Vol. 11, No. 1, 2004, pp. 31-43.

[5] HRYNIEWICZ T.: Technology of Surface and Coatings, Publishing house: Koszalin University of Technology, Koszalin 2004 (In polish: Technologia powierzchni i powłok, Wydawnictwo Uczelniane Politechniki Koszalińskiej, Koszalin)

[6] ULEWICZ R., NOVY F., SELEJDAK J., Fatigue Strength of Ductile Iron in Ultra-High Cycle Regime, Advanced Materials Research, Vol. 874, 2014, pp. 43-48.

[7] ULEWICZ R., SZATANIAK P., NOVY F., Fatigue Properties of Wear Resistant Martensitic Steel, 23rd International Conference on Metallurgy and Materials (METAL 2014).

[8] DUDEK A., ADAMCZYK L., Properties of hydroxyapatite layers used for implant coatings, Optica Applicata, Vol. 43, No. 1, 2013, pp. 143-151.

[9] DUDEK A., Investigations of microstructure and properties in bioceramic coatings used in medicine. Archives of Metallurgy and Materials, Vol. 56 , No. 1, 2011, pp. 135-140.

[10] SCENDO M., RADEK N., TRELA J., The influence of electrospark and laser treatment upon corrosive resistance of carbon steel, Advanced Materials Research, Vol. 874, 2014, pp. 107-112.

[11] RADEK N.,, ANTOSZEWSKI B., Influence of laser treatment on the properties of electro-spark deposited coatings, Kovove Materialy-Metallic Materials, Vol. 47, No.1, 2009, pp. 31-38.

[12] FABIAN P., JANKEJECH P., KYSELOVA M., Simulation of roundness, hardness and microstructure of bearing rings with thin cross sections by using sysweld, Komunikacie, Vol. 16, No. 3A, 2014, pp. 124-129.

[13] BRONCEK J., DZIMKO M., HADZIMA B., TAKEICHI Y., Experimental investigations of aluminium alloys 2024-T3 form in terms of tribocorrosion characteristics, Acta Metallurgica Slovaca, Vol. 20, No. 1, 2014, pp. 97-104.