INNOVATIVE THIN COATING INTENDED TO PROTECT NON-FERROUS MATERIALS

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Abstract

The purpose of protective coatings is not only to provide the protected material a new, attractive design, but also new properties, longer durability, corrosion resistance, resistance to specific environments etc. These advantages of protective coatings are used in various branches of engineering, for various corrosivity of the environments, for different types of substrates, etc. The subject of this paper is on the type of substrate, which researched protective properties of the innovative thin coating applied to the non-ferrous substrate. Transparent waterborne coating containing nanoparticles was used for experimental work, which was applied to two types of non-ferrous materials. These non-ferrous materials are the most widespread in technical practice and in conjunction with the advanced technology of protective coatings containing nanoparticles makes this issue very topical. Present experimental results show us a significant potential for industrial use.

Keywords: Protective coating, corrosivity of the environments, non-ferrous material, coating, nanoparticles

1. INTRODUCTION

The paper explores the study of innovative thin coatings applied to the non-ferrous materials. Non-ferrous materials are specific areas in surface treatments requiring specific conditions not only in the process of preparing the surface, but they are placed on the paint itself in high volume. In the area of surface preparation is always better to create height of profile to effect maximum adhesion to the substrate and thereby also maximum durability of the coating. Non-ferrous materials are often prepared by chemical pre-treatment. And this chemical pre-treatment has been the basis for research and experimental works in the corrosion protection of non-ferrous materials with the use of innovative coating containing nanoparticles.

2. SPECIFICATION OF EXPERIMENTAL MATERIALS

The detailed description of the experimental materials cannot be disclosed due to the ongoing patent proceedings.

We used the following materials:

- non-ferrous substrate materials:

TYP A - dimension 152 x 102 x 0.64 mm; ***TYP B*** - dimension 150 x 100 x 3 mm,

- coating: **transparent waterborne coating containing nanoparticles.**

3. EXPERIMENTAL MEASUREMENTS

The experimental works have been focused on laboratory testing of innovative paint system applied to non-ferrous materials with the evaluation of mechanical properties and corrosion resistance:

Surface evaluation of the substrate

- The measurement of surface roughness according to EN ISO 4287, we used a measuring equipment Mitutoyo Surftest SJ-301.

Surface pre-treatment before the paint application

- Selecting degreasing agent; technological process of degreasing.

- Surface tension measurement of the substrate using test inks - the test ink is applied by brush onto the substrate. If the line of ink will remain "unchanged" on surface of the material for about 2 seconds, then the surface is suitable for application of the coating system. For example if the drops were not formed. The surface suitable for application of the coating has a value of surface tension in the range from 35 to 40 $mN \cdot m^{-1}$. The larger value of surface tension means the rigorous measurement. For this particular measurement the test ink with a value 38 $mN \cdot m^{-1}$ was used.
- The assessment of dust on the surface according to ISO 8502-3 - this standard describes a method for rating dust residues on cleaned surface prepared for painting. [1] Measurement consists of bonding of adhesive tape to the surface of material prepared for painting. The tape with entrapped dust is removed, placed on a contrasting background and performs visual evaluation.
- The measurement of surface roughness after degreasing in accordance with EN ISO 4287, where we used a measuring equipment Mitutoyo Surftest SJ-301.

Application of transparent waterborne coating, technological process

- Measuring of wet film thickness (*WFT*) and dry film thickness (*DFT*). The wet film thickness (*WFT*) was measured using a stainless steel wet film comb; dry film thickness was measured by a digital thickness gauge ELCOMETER 456 with the FNF probe.

Adhesion tests of coating system, corrosion test

- Pull of test according to EN ISO 16276-1 - the standard defines how to perform pull-off test on paint system. The test result is the minimum tensile stresses that must be expend to tear the weakest interphase (adhesive fracture) or weakest component (cohesive fracture) test arrangement. For the measurements was used measuring device - ELCOMETER F106 (working range 0-22 MPa).
- Cross-cut test and X-cut test according to EN ISO 16276-2 - the standard describes the procedure to evaluate the resistance of coating systems which is cut in the form of a right-angled grid (cross cut test) or in the X-form (cross section) so that the cut penetrate through to the substrate. [2] The measuring sets used for these parts were ELCOMETER 141 PIG for cross-cut test and SP3000 for X-cut test.
- The corrosion tests in artificial atmospheres - Salt spray tests according to EN ISO 9227 - salt spray corrosion test was carried out by NSS method (in neutral sodium chloride salt spray). The test period was set at 100 hours. The assessment of the test was performed visually according to EN ISO 4628. The corrosion test was performed in the corrosion chamber LIEBISCH S400 M-TR.

4. RESULTS OF EXPERIMENTAL MEASUREMENTS

4.1. Assessment of substrate surface

Table 1 The measurement of substrate surface roughness

Type of substrate	*Ra* (μm)		*Rz* (μm)	
	Direction along	Direction cross	Direction along	Direction cross
TYP A	0.16	0.45	1.05	2.72
TYP B	5.54	5.79	28.98	30.68

4.2. Surface pre-treatment

The surface pre-treatment was performed by chemical cleaning - degreasing. We used waterborne degreaser SIMPLE GREEN. Technological conditions of degreasing are stated in **Table 2**. After degreasing followed tests with the aim of assess the condition of the surface before application of the coating system. The results of the tests are stated in **Tables 3, 4 and 5**.

Table 2 Technological conditions of degreasing

Degreaser	SIMPLE GREEN
Mixing ratio	1:10 (SIMPLE GREEN : water)
pH of degreaser	11.32
Temperature of degreaser	23.1°C
Time of degreasing	10 min.
Method of degreasing	Dip
Rinse	Rinse with cold water (temperature of rinse water 18-23°C), rinsing method: dip, time of rinse: 5 min
Drying	100°C, time of drying 10 min, electric drying oven type SN30/4

Table 3 Surface tension measurement - test ink 38 mN·m^{-1}

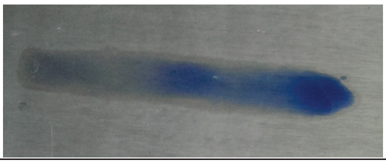
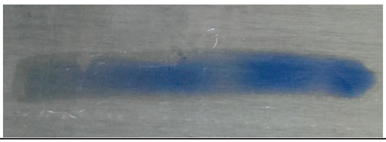
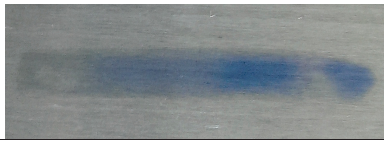
Number of measurements	Result	Photographs
1	Surface suitable for coating application	
2	Surface suitable for coating application	
3	Surface suitable for coating application	

Table 4 Assessment of dust on substrate according to ISO 8502-3

Type of substrate	The size of dust particles	The degree of dust	Max. permissible degree	Result
TYP A	2	2	2/2 *	Suitable
TYP B	0	1	2/2 *	Suitable

* The size of dust particles/the degree of dust

Table 5 Measurement of surface roughness after degreasing

Type of substrate	*Ra* (µm)		*Rz* (µm)	
	Direction along	Direction cross	Direction along	Direction cross
TYP A	0.29	0.41	1.68	2.14
TYP B	4.21	4.88	21.92	25.04

Following the degreasing test, an increase of the surface roughness parameter was *Ra* on the sample *TYP A*. Increased surface roughness values may positively affect the final adhesion of the coating system to the substrate. The opposite phenomenon, thus reducing surface roughness value was found in the sample *TYP B*.

4.3. Application of transparent waterborne coating

Table 6 Technological process of applying coating system

Method of application	Brush
Thinning the paint	10%, water
Temperature of the environment	22.9°C
Temperature of the substrate	23.4°C
Relative humidity	27.4%
Dew point temperature	3.5°C

Table 7 The results of measurements of wet film thickness (*WFT*)

Type of substrate	*WFT* (µm)
TYP A	150 to 200
TYP B	150 to 200

Table 8 The results of measurements of dry film thickness (*DFT*)

Type of substrate	*DFT* (µm)			
	n (-)	*DFT* (µm)	*Min. DFT* (µm)	*Max. DFT* (µm)
TYP A	12	51.30	39.30	69.60
TYP B	12	75.62	36.70	106.00

n - number of measurements, *DFT* - dry film thickness, *Min. DFT* - minimum value of dry film thickness, *Max. DFT* - maximum value of dry film thickness

4.4. Adhesion tests of coating system

Table 9 Results of adhesion tests

Type of substrate	Pull of test		Cross-cut test	X-cut test	Photographs		
	Adhesive strength (MPa)	Characteristics of the fracture surface (%)	Degree (-)	Degree (-)			
TYP A	- *	-	0	0	-		
TYP B	6.7	100% B/Y **	0	0			

* Due to inadequate thickness of the substrate *TYP A*, it was not possible to carry out the pull of test

** B/Y - adhesion fracture between coating (B) and glue (Y)

4.5. Corrosion tests in artificial atmospheres - Salt spray tests according to EN ISO 9227

The samples were cut before testing; the length of scribe was 50 mm. The scribe simulates damage to the coating in real conditions. The test period was set at 100 hours with a continuous evaluating after 24 hours. The test was evaluated visually according to EN ISO 4628, parts 2, 3, 4, 5 and 8.

Table 10 The evaluation of corrosion tests in artificial atmosphere according to EN ISO 4628

Type of substrate	Test period	Degree of rusting acc. to EN ISO 4628-3	Degree of blistering acc. to EN ISO 4628-2	Degree of cracking acc. to EN ISO 4628-4	Degree of flacking acc. to EN ISO 4628-5	Degree of delamination and corrosion around a scribe EN ISO 4628-8
	(Hours)	(Degree)	(Degree)	(Degree)	(Degree)	(Degree)
TYP A	24	Ri 0	0 (S0)	0 (S0)	0 (S0)	0
	100	Ri 0	0 (S0)	0 (S0)	0 (S0)	0
TYP B	24	Ri 0	0 (S0)	0 (S0)	0 (S0)	0
	100	Ri 0	5 (S2)	0 (S0)	0 (S0)	0

Notes:

Degree Ri 0 - area of corrosion is equal to 0%;

Degree 0 (S0) - surface without blistering, cracking, flacking, delamination and corrosion around a scribe;

Degree 5 (S2) - surface is densely covered with blisters, blisters size are already visible to the naked eye or with the correction of visual defects. [3]

5. CONCLUSION

The non-ferrous materials are still widespread in technical praxis. The development brings stronger demands placed on them and these requirements are related to the area of corrosion resistance. This paper is focused on surface treatment of non-ferrous materials by using modern waterborne transparent coating containing nanoparticles. Combining the existing excellent experimental results, nanotechnology and application of the paint in thin layers give this technology a significant potential for industrial use, not only for short term but also for long term corrosion protection of non-ferrous materials.

REFERENCES

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