Chapter 12

Jaroslava Svobodová[1] *Sylvia Kuśmierczak*[2] *Nataša Náprstková*[3]

THE STATISTIC EVALUATION OF THE QUALITY OF THE SURFACE TREATMENTS

Abstract: The article deals with evaluation of the quality of the surface treatment on the service life of the experimental samples. We have tested two sets of samples, which was pre-treated by the different ways. We have used one kind of material – laboratory used material Q-panel Fe - for the experiment. The material was pre-treated by mechanical pre-treatment (soft blasting) and chemical pre-treatments (alkaline degreasing, ferric phosphate and zirconium nanopassivation). For all samples it was measured the thickness of the coated layer before insertion into the spray chamber at five points of the each experimental sample and for all chemical pre-treatments was measured surface roughness. The results are summarized in tables and graphs. Then the samples were placed in to corrosion chamber and subjected to salt spray corrosion test. The sample loading time was chosen according to the standard for 480, 720 and 1000 hours. The samples were compared with each other and their status was evaluated after corrosive load in corrosion chamber after removal from the corrosive environment. Experimental samples were statistically evaluated according to the thickness measurement of coated layer, chemical pre-treatment surface roughness and their effect on the corrosion resistance of painted sheet metal.

Key words: chemical surface pre-treatment, mechanical surface pre-treatment, coating thickness measurement, surface roughness, corrosion resistance

12.1. Introduction

The coating thickness is one of the basic criteria for the evaluation of the corrosion resistance and for the prediction of the life time of the engineering products, construction elements, constructions and so on. The

---

[1] Ing., Faculty of Production Technology and Management, University of J.E. Purkyně in Ústí nad Labem, Czech Republic, svobodova@fvtm.ujep.cz

[2] Ing., PhD., Faculty of Production Technology and Management, University of J.E. Purkyně in Ústí nad Labem, Czech Republic, kusmierczak@fvtm.ujep.cz

[3] Ing., Ph.D., Faculty of Production Technology and Management, University of J.E. Purkyně in Ústí nad Labem, Czech Republic, naprstkova@fvtm.ujep.cz

coating thickness applied on the base material is the distance between the coating surface and the surface of the base material. The surface measurement methods are given by the type of the base material, the type of the coating and by its expected thickness that means by the required accuracy and by the range of the measuring device. For measurement of the organic coating thickness are used methods which are listed in the standard ČSN EN ISO 2808 Paints and varnishes – Determination of film thickness. The measurement methods of the coating thickness are normalized in ČSN EN ISO 3882 Metallic and other inorganic coatings – Review of methods of measurement of thickness. Each standard reports the specific views of the using the individual practice of the coating thickness measurement (KREISLOVÁ, 2008).

The coating thickness is one of the parameters which have influence on the corrosion resistance of the material and on the life time of the applied coating. The second parameter is the surface roughness. The surface roughness is very important because on the roughness depends the adhesion of the coating. The establishment of an appropriate anchor profile is the role of the mechanical and chemical pre-treatments. Using the mechanical pre-treatments we increase the surface roughness. For the increasing of the surface roughness of the metal sheets we most often use soft blasting or grinding. Chemical pretreatments have the considerable influence too. For example the phosphates create tertiary phosphates on the surface of the material and thus increase the adhesion of the coating.

The aim of the experiment is the evaluation of the influence of the coating thickness and the surface roughness on the corrosion resistance of the coated metal sheets.

12.2. Experimental samples

The experimental samples were prepared in two variants. The basic material is Q-panel Fe used for the laboratory experiments of the coatings. This base material is low carbon unalloyed steel and its chemical compound is listed in the Table 12.1.

Table 12.1. Chemical composition of the base material Q-panel Fe

Material	max. C %	max. Mn %	P %	S %
Q-panel Fe	0.12	0.60	0.045	0.045

This experimental material is supplied as low blasted. So chemical pre-treatment is low blasting and the surface roughness of the base material Q-panel Fe will be measured in the experiment. The first step of the experiment is the preparation of the samples specifically the chemical pre-treatment. The samples were pre-treated due to the Table 12.2.

Table 12.2. Chemical pre-treatment of the samples

Base material	A	C
Q-panel Fe	Alkaline degreasing **(CC)** + zirconium nanopassivation **(Zr)**	Alkaline degreasing **(CC)** + phosphate **(Feph)** + zirconium nanopassivation **(Zr)**

CC – is the classical process of the chemical alkaline degreasing, Feph – is the iron phosphate, Zr – is the new type of the chemical pre-treatment based on nanotechnology. This nanotechnology product can in the future replace classical phosphate process. The benefits of this zirconium nanopassivation product are: multimetalic use – steel, aluminum, zinc; low working temperatures; ecological product et cetera (PALKO, 2010). The chemical pre-treatment we performed in the Faculty of production technology and management laboratory. The samples we prepared in our laboratory were subjected to the surface roughness measurement.

The next step was thickness measurement of the samples with the coating which we obtained from the supplier. For this samples were used the same chemical pre-treatments like the samples shown above and on the surface of this samples was used powder coating TIGER Drylac®. The thickness of the coating must be in the range – minimum 60 – 80 μm and it should not exceed more than 110 μm. The labeling of the samples is shown in the Table 12.3.

Table 12.3. The labeling of the experimental samples

	Corrosion load time			
Pre-treatment	480 hours			
CC+Zr	A1-1	A1-2	A1-3	A1-4
CC+Feph+Zr	C1-1	C1-2	C1-3	C1-4
Pre-treatment	720 hours			
CC+Zr	A2-1	A2-2	A2-3	A2-4
CC+Feph+Zr	C2-1	C2-2	C2-3	C2-4
Pre-treatment	1 000 hours			
CC+Zr	A3-1	A3-2	A3-3	A3-4
CC+Feph+Zr	C3-1	C3-2	C3-3	C3-4

12.3. Experimental methods

At first before the corrosion load test we measured **coating thickness**. The measuring of the coating thickness was performed by the use of thickness gauge PosiTector 6000 (Figure 12.1).

Fig. 12.1. Thickness gauge PosiTector 6000.

After thickness measuring we give the samples to the **corrosion chamber**. The conditions of the corrosion chamber are shown in the Table 12.4.

Table 12.4. The corrosion chamber conditions

Test parameters	**Neutral salt spray**
Temperature	35°C ± 2°C
The average rate of accumulation spray mist of the horizontal collector area 80cm²	1,5 ml/h ± 0,5 ml/h
Concentration of sodium chloride (accumulated in solution)	50 g/l ± 5 g/l
pH (accumulated in solution)	6,5 až 7,2
Corrosion load time	480, 720, 1000 hours

The corrosion time and corrosion load were set according to the standard ČSN EN ISO 9227. Before the placing of the experimental samples in to the corrosion chamber we make the cut on the surface of the samples. It is due to the evaluation of the delamination and corrosion. One of the all samples from each group stayed without this cut.

Beyond the thickness measurement and corrosion test we measured the surface roughness. We prepared samples without the coating. The chemical pre-treatment was the same as it is show above. To the roughness measurement we used the measuring device Hommel tester T 1000 (figure 12.2)

Fig. 12.2. Hommel Tester T 1000.

The surface roughness is defined according to the standard ČSN EN ISO 4287 in CZ, which contents the exact definitions of the roughness parameters, material proportion of profile including calculations, classification of admissible inequality, marking and methods of evaluating. Parameter Ra – arithmetical mean deviation of the assessed profile is the most commonly used currently in the practice, as well as the largest height of the profile Rz and the total height of to profile Rt, which were also evaluated in the experiment [5].

12.4. Measurement results

Coating thickness measurement

Table 12.5. The coating thickness measurement – sample group A

Sample	Thickness measurement					The average thickness of the coating [μm]	Standard deviation	Max	Min
A1-1	180	146	84	242	146	159,6	51,55812	242	84
A1-2	102	74	58	88	72	78,8	14,99867	102	84
A1-3	100	92	74	98	98	92,4	9,583319	100	74
A1-4	70	70	52	96	74	72,4	14,05133	96	52
A2-1	128	140	52	150	132	120,4	35,01771	150	52
A2-2	98	76	74	108	68	84,8	15,41947	108	68
A2-3	112	92	82	126	94	101,2	15,72768	126	82
A2-4	108	110	86	124	112	108	12,32883	124	86
A3-1	100	102	62	100	104	93,6	15,86947	104	62
A3-2	90	70	66	86	64	75,2	10,70327	90	64
A3-3	100	90	72	98	110	94	12,7122	110	72
A3-4	86	100	68	102	110	93,2	14,78377	110	68

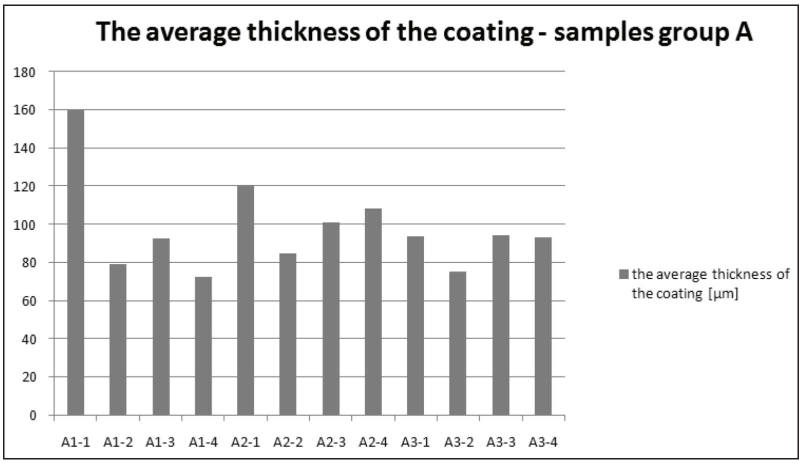

Fig. 12.3. The thickness measurement of the sample group A.

Table 12.6. The coating thickness measurement – sample group C

Sample	Thickness measurement					The average thickness of the coating [µm]	Standard deviation	Max	Min
C1-1	180	122	94	168	206	154	40,49691	206	94
C1-2	96	86	76	88	90	87,2	6,523803	96	76
C1-3	108	102	84	112	110	103,2	10,16661	112	84
C1-4	110	102	90	132	98	106,4	14,33318	132	90
C2-1	128	118	62	122	132	112,4	25,65619	132	62
C2-2	112	118	102	128	116	115,2	8,447485	128	102
C2-3	96	112	82	128	126	108,8	17,6454	128	82
C2-4	82	110	78	88	110	93,6	13,76372	110	78
C3-1	146	128	87	134	140	127	20,88061	146	87
C3-2	94	96	100	104	112	101,2	6,4	112	94
C3-3	94	74	68	94	82	82,4	10,46136	94	68
C3-4	104	128	98	120	132	116,4	13,2906	68	98

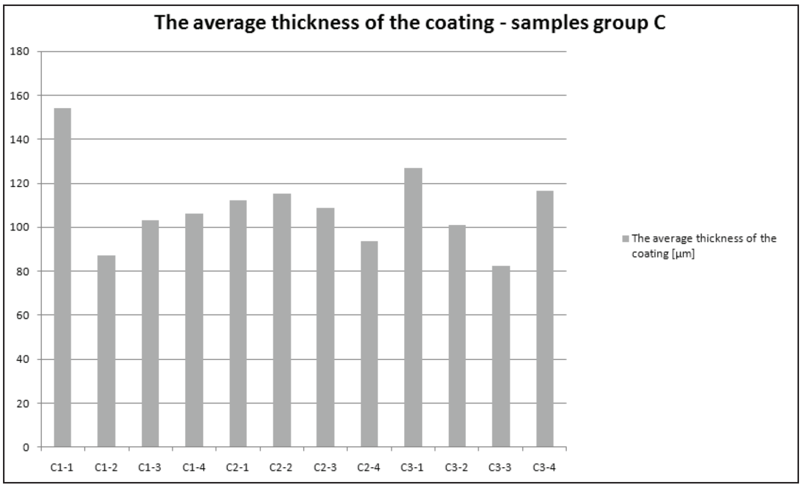

Fig. 12.4. The thickness measurement of the sample group C.

Corrosion test

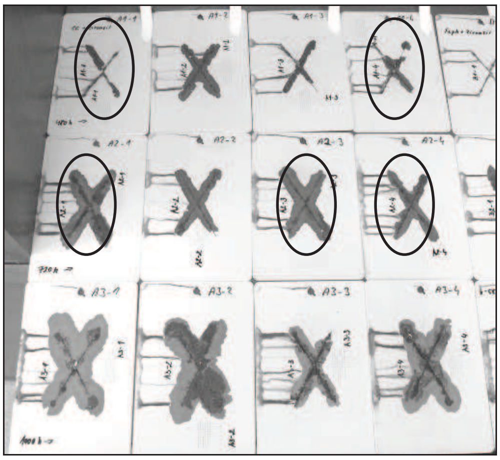

Fig. 12.5. The samples after corrosion - A.

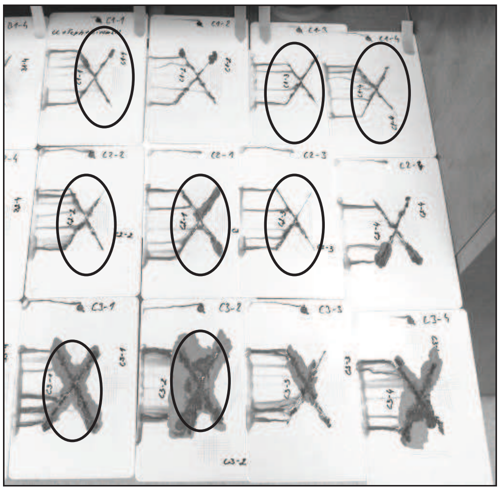

Fig. 12.6. The samples after corrosion - C.

Roughness measurement

The surface roughness measurement was performed on five places of the sample surface. We performed longitudinally and laterally measurement.

Table 12.7. The surface roughness measurement

Surface pre-treatment	**Average roughness –**			**Average roughness |**		
	Ra	Rz	Rt	Ra	Rz	Rt
CC + Zr	0,595	3,595	4,448	0,486	3,283	4,425
CC + Feph + Zr	0,602	3,509	4,591	0,473	3,084	4,082
	Standard deviation –			**Standard deviation |**		
CC + Zr	0,0424	0,2322	0,4981	0,0882	0,4496	0,8298
CC + Feph + Zr	0,0423	0,2735	1,1941	0,0676	0,2949	0,4407

*– measured longitudinally on the surface of metal sheet

*| measured laterally on the surface of metal sheet

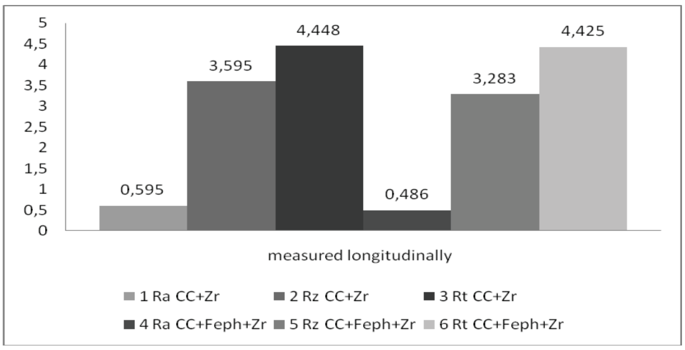

Fig. 12.7. Surface roughness measurement - longitudinally.

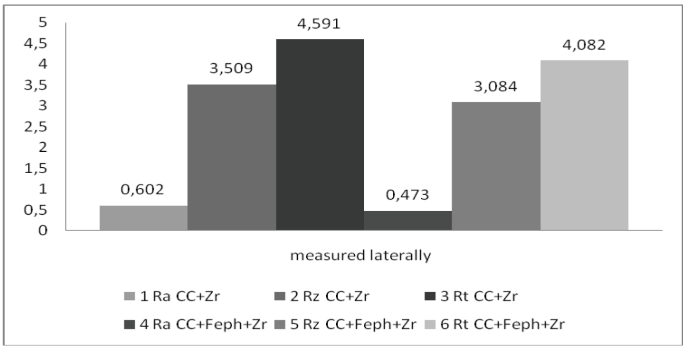

Fig. 12.8. Surface roughness measurement - laterally.

12.5. Conclusion and discussion of the results

When we look at the Tables 12.5 and 12.6, we can conclude that in the Table 12.5 is five samples which does not comply to the requirement 60 – 80 µm (110 µm max.). There is a lower thickness by two samples than the desired thickness and by three samples there is the coating thickness higher than the desired thickness. Samples from the group C have a greater difference in the thickness of the coating than the samples from the sample group A. There are eight samples which have the higher coating thickness than the desired thickness in the group C. If we look at the Pictures 12.5, 12.6 and compare the samples in each groups we can conclude that the coating thickness despite unsatisfactory coating thickness have not significant influence on the corrosion resistance of the experimental samples.

The results from the surface roughness measurement are shown in the Table 12.7 Form the results we can conclude that the longitudinally roughness by the group A – CC+Zr (see Figure 12.7) have the higher roughness that the sample group C – CC+Feph+Zr. The similar results are by the laterally surface roughness measurement (see Figure 12.8). The difference by the both pre-treatment is however in the order of tenths of μm. We can therefore consider the surface roughness for almost the same by the both of the pre-treatments.

In terms of corrosion resistance we can say that the sample group A has lower corrosion resistance than the sample group C. We can conclude that from the experience of the other research the pre-treatment CC+Feph+Zr has still better corrosion resistance than the new type of nanopassivation product and the pre-treatment CC+Zr (KUŚMIERCZAK S. 2012). The use of Zr nanopassivation is in this time suitable for the sealing of the phosphate because this type of pretreatment is porous or for the indoor use. In this experiment the coating thickness and the surface roughness did not have the significant influence on the corrosion resistance of the experimental samples. Despite this we recommend the compliance with the technological process of the coating applications.

Bibliography

1. KREISLOVÁ K. 2008. *Přehled metod měření tloušťky povlaků.* SVÚOM Praha. ISBN 978-80-7283-251-4.
2. PALKO M. 2010. *ZircaSil® - nova řada již známého systému NANO-technologií pro povrchové úpravy.* Available at www: http://itsbrno.cz
3. NARAYANAN S. 2005. *Surface Pretreatment by Phosphate Conversion Coatings – A Review.* Rev.Adv.Mater.Sci. 9.
4. KUŚMIERCZAK S., SVOBODOVÁ J. 2012. *Microscopic Evaluation of Protective Coating by Coated Sheets after Corrosion Load.* Manufacturing Technology, Journal for Science, Research and Production, Vol. 12, No. 13, pp. 151-157. ISSN 1213-2489.

Acknowledgments

Authors are grateful for the support of grant IRP 2013 UJEP and thanks to the co-financed by **SD-30/04/13-16** Severočeské Doly Chomutov a.s.

SD Pomáháme