TRUCK CABIN CORROSION RESISTANCE OBSERVATION IN ARTIFICIAL ATMOSPHERE

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Abstract. This article describes observation of corrosion resistance coating systems used on the cabin of a truck from the Czech truck producer Avia. On the quality of the coating systems for trucks are made very high demands, for weathering, chemical and UV resistance and long-term corrosion resistance. These days optical criterions are not less important, which are last days very close to the passenger vehicle quality, because high competitive environment pushes truck producers to increase the truck quality in all fields, starting at engines and axles, electronics, safety elements and not finishing with painting systems, which give the final look to every truck. And as it is known and valid more and more for trucks as well, design and look is selling. One of the most important quality criterions is corrosion resistance, which was tested acc. EN ISO 9227 Corrosion tests with artificial atmosphere - Salt spray test, supplemented by observation and photo documentation during testing every 240 h, 480 h, 720 h, 1000 h, 1250 h, 1500 h, 1750 h, 2000 h. The main intention of this testing is to evaluate all painting systems used on the cabin and find the most critical areas from the corrosion resistance view and observe the corrosion process at time intervals. Then, from this observation to find the weakest and strongest painting system of the cabin and propose corrective actions.

Keywords: corrosion, truck cabin, cataphoretic coating, painting.

Introduction

Protection against corrosion in automobiles is of great importance from the point of view of both, the national economy and private car owners. The automotive industry requires organic protective coating with very high resistance to degradation. Coating must protect the substrate against corrosion attack and keep it undamaged for long time while at the same time offering persistently good aesthetic properties, which means a high level of stability towards photo-oxidative degradation, mechanical abrasion and other harmful processes [1].

As well known, the automotive sector has contributed on a large scale to achieving compliance with increasingly restrictive environmental legislation in the field of surface treatments, above all in anticorrosive coatings. Today, it can be stated that the anticorrosive protection of almost all automotive bodywork includes a cataphoretic primer [2]. Although electrodeposition was introduced in the automotive industry in the 1960s, cathodic electrodeposition rapidly replaced anodic electrodeposition in the 1970s due to the greater anticorrosive protection that it conferred and to other film characteristics, which had never been attained with other techniques. At the beginning of the 1980s, cathodic systems were based on modified epoxy resins contained amino groups, systems which were described by Pierce [3].

They were dispersed in water by neutralizing the amino groups with organic acids. The resins were cross-linked by blocked isocyanates. Pigmentation was based on titanium dioxide and extender pigments. Special lead-containing pigments, such as silicates, were used as anticorrosive agents, although lead was also used to catalyse the curing reactions. The first lead-free systems only came onto the market in the 1990s, coinciding with attempts to meet other challenges such as achieving reduction in the volatile organic solvent content and lowering the curing temperature [4-6].

The electrodeposition process is controlled by many parameters, such as mean applied voltage, anode-to-sample distance or temperature. All of these have an important effect on the final performance of the primer. For example, it is well known that the ability of the cataphoretic process to deposit a film of the paint in highly recessed areas increases the deposition voltage usually set by a phenomenon called film rupture, which causes blemishes [7-10]. Nowadays, the anticorrosive protection of almost all-automobile bodywork includes a cataphoretic primer (98 % of cars are primed with cathodic electrocoat) [11].

In order to enhance the adhesion and the corrosion protection properties of the cataphoretic coating, the metal substrate is usually subjected to a surface conversion pre-treatment [12]. The automobile bodywork is composed of different metallic substrates such as hot dip galvanized steel (HDG), electrogalvanized steel (EZ), steel and aluminium alloys. These metallic parts are assembled before surface treatment. The conversion treatment widely used is the trication phosphatization which is after activation compatible with all these substrates. Nevertheless, this treatment presents some environmental and economical drawbacks [13; 14].

Materials and methods

As the cabin is a very complicated unit containing many molded parts welded together with different welding technologies, it is very important to study all these painting systems on the critical areas, which are just these welded connections that mean high temperature affected areas steel substrate. The same like most truck producers Avia truck as well uses the most common welding technologies, spot welding, welding in protective atmosphere CO_2, further resistance welding is used to fix screws and nuts. This all is very interesting to compare to raw electrolytically zinc coated steel substrate without temperature affection. So the sample panels were prepared:

1. Panels without welding (temperature not affected).
2. Spot welded.
3. MAG – welded in protective atmosphere CO2.

4, 5. Fixed screw and nuts by resistance welding.

In this article all painting systems used on the truck are described, i.e., in cabin interior cataphoretic coating only or with combination with primer is used, in the blank space cathaphoretic coating + wax, on the cabin bottom cathaphoretic coating + plastosol + primer + top coat and on the top of the cabin cataphoretic coating + primer + topcoat is used. On the base of this fact the sample panels were prepared:

1. Only cataphoretic primer (PPG Powercron 6200).
2. Cataphoretic primer + wax (WEDOLIT V 468-6705).
3. Cataphoretic primer + filler (PPG 1K waterborne topcoat).
4. Cataphoretic primer + plastisol (Henkel Terotex 8255M) + filler + topcoat.
5. Cataphoretic preimer + filler + topcoat (PPG PUR 1K Waterborne topcoat).

Testing was done in the corrosion cabinet acc. EN ISO 9227 - Corrosion tests with artificial atmosphere - Salt spray test by method NNS, which were extended by progressive observation and photo documentation every 120 h until 2000 h. So every 240 h visually corrosion and blisters have been assessed according to:

- EN ISO 4627-1 General information and designation system;
- EN ISO 4627-2 Assessment of degree of blistering;
- EN ISO 4627-8 Assessment of degree of delamination and corrosion around a scribe;
- EN ISO 4627-10 Assessment of degree of filiform corrosion.

Measuring and observation has been done on all 5 painted panels of each sample and from these measurements averages have been calculated. Tested panels from electrolytically zinc coated steel DC05+ZE acc. EN10152 (according DIN 17163 St 15 ZE), dimensions 150 mm x 70 mm x 1.2 mm were used. The chemical composition of steel: C – 0.06 %, P – 0.025 %, S – 0.025 %, Mn – 0.35 %.

Results and discussion

For the purpose of this article two methods of evaluation of all painting systems have been selected, the first is assessment of the degree of blistering according to EN ISO 4627-2 and the second is assessment of the degree of delamination and corrosion around a scribe according to EN ISO 4627-8. All panels were tested before and after testing for direct adhesion according to ISO 2409 with results GT0. Dry film thickness (DFT) has been measured according to EN ISO 2808 (µm).

Assessment of the degree of blistering according to EN ISO 4627-2 (Table 1, 2) allows evaluation of the size and volume of blisters. This method was upgraded and improved for evaluation and photodocumentation in time intervals. From this it was possible for all painting systems to express characteristics for each painting system. The second method is measuring, which allows to measure in milimeters the degree of filiform corrosion. As well as in the first method, measuring was done in time intervals and from the measured values it was possible to express characteristics of each painting system on panels welded by different welding technologies.

Table 1

Dry film thickness and observation of assessment of degree of blistering acc. EN ISO 4627-2

Painting system	Welding technology	Nr	DFT, µm	Observing time, h								
				0	240	480	720	1000	1250	1500	1750	2000
			Ø	Vol./Size								
Cataphoretic primer	Not welded	1.	29.6	0/0	0/0	0/0	2/2	2/4	3/4	3/5	4/5	4/5
	MAG	2.	29.7	0/0	0/0	2/3	2/4	3/5	3/5	3/5	4/5	4/5
	spot welding	3.	29.3	0/0	0/0	2/2	2/3	3/4	3/5	3/5	4/5	4/5
	Fixed Nut	4.	29.4	0/0	0/0	0/0	0/0	2/2	2/2	3/4	3/4	4/5
	Fixed Screw	5.	29.5	0/0	0/0	0/0	0/0	2/2	2/2	3/4	3/4	4/5
Cataphoretic primer + wax	Not welded	6.	220.0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	MAG	7.	280.0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	spot welding	8.	240.0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Fixed Nut	9.	200.0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Fixed Screw	10.	235.0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Cataphoretic primer + Filler	Not welded	11.	66.4	0/0	0/0	0/0	2/2	2/4	3/4	3/5	4/5	4/5
	MAG	12.	67.8	0/0	0/0	2/3	2/4	3/5	3/5	3/5	4/5	4/5
	spot welding	13.	67.9	0/0	0/0	2/2	2/3	3/4	3/5	3/5	4/5	4/5
	Fixed Nut	14.	66.5	0/0	0/0	0/0	0/0	2/2	2/2	3/4	3/4	4/5
	Fixed Screw	15.	65.9	0/0	0/0	0/0	0/0	2/2	2/2	3/4	3/4	4/5
Cataphoretic primer + Filler + Topcoat	Not welded	16.	97.9	0/0	0/0	0/0	0/0	2/4	3/4	3/4	3/4	3/4
	MAG	17.	102.8	0/0	0/0	2/2	2/3	3/4	3/4	3/4	3/4	3/4
	spot welding	18.	100.2	0/0	0/0	2/2	2/2	2/4	3/4	3/4	3/4	3/4
	Fixed Nut	19.	100.1	0/0	0/0	0/0	0/0	0/0	0/0	2/2	2/4	2/4
	Fixed Screw	20.	99.5	0/0	0/0	0/0	0/0	0/0	0/0	2/2	2/4	2/2
Cataphoretic primer + Plastisol+ Filler + Topcoat	Not welded	21.	651.1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	MAG	22.	698.0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	spot welding	23.	677.5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Fixed Nut	24.	645.9	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Fixed Screw	25.	652.6	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0

Table 2

Observation of assessment of degree of blistering acc. EN ISO 4627-2

Painting system	Welding technology	Nr	Observing time, h								
			0	240	480	720	1000	1250	1500	1750	2000
			L/M, mm								
Cataphoretic primer	Not welded	1.	0/0	0/1	1/3	2/4	2/4	2/4	3/5	4/5	4/5
	MAG	2.	0/0	1/1	1/3	1/3	3/7	3/7	3/8	3/8	5/9
	spot welded	3.	0/0	1/2	2/5	4/6	4/6	5/8	5/9	5/11	8/12
Cataphoretic primer + wax	Not welded	6.	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	MAG	7.	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	spot welded	8.	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Cataphoretic primer + Filler	Not welded	11.	0/0	0/1	1/3	2/4	4/6	4/8	5/8	5/11	5/12
	MAG	12.	0/0	1/2	2/5	3/6	5/7	5/7	5/8	5/9	6/10
	spot welded	13.	0/0	2/4	3/5	4/7	4/7	6/9	6/9	6/12	7/13
Cataphoretic primer + Filler + Topcoat	Not welded	16.	0/0	0/1	0/1	1/2	2/4	3/6	3/6	3/8	4/8
	MAG	17.	0/0	1/1	1/2	1/3	2/4	4/5	4/6	4/8	4/10
	spot welded	18.	0/0	1/1	1/2	1/2	2/2	3/3	3/3	3/4	3/4
Cataphoretic primer+Plastisol+ Filler+Topcoat	Not welded	21.	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	MAG	22.	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	spot welded	23.	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0

1. Spot welding

Comparison of different painting systems on the panels welded by spot welding expressed by EN ISO 4628-2 is shown in the graphs in Fig. 1. From this we can say that on volume and size of blisters panels with cataphoretic primer have the same characteristics as well as panels with cataphoretic primer + filler. The second layer of filler has no affect to corrosion resistance. But the third layer of topcoat can be significantly affected by the blistering process. There you can see that the final volume is lower and increasing later as that of the previous two painting systems. Definitely best results without any blisters and corrosion were on panels painted by cataphoretic primer + wax and on the painting system using on the bottom of the cabin included plastisol.

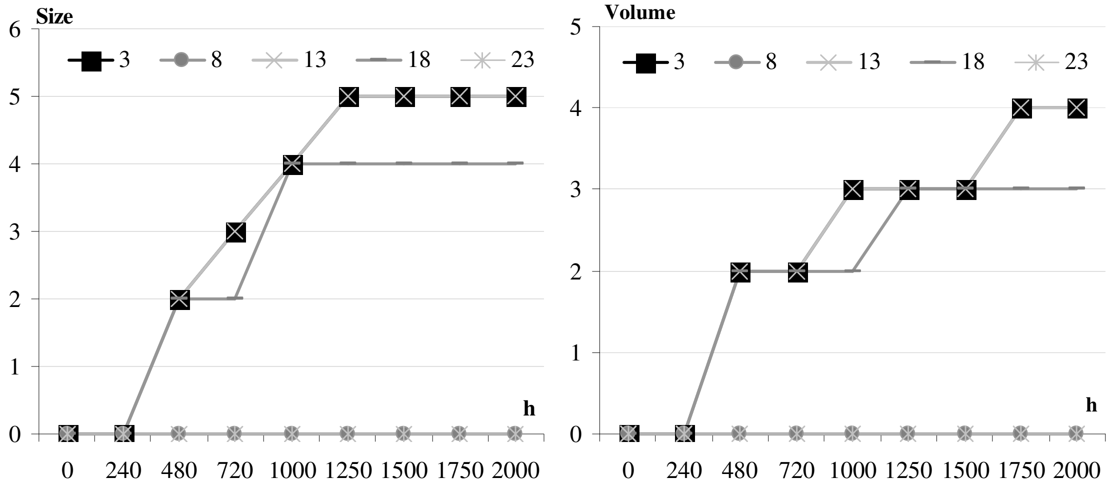

Fig. 1. **Spot welding panels characteristics from degree of blistering according EN ISO 4627-2**

The second used method of assessment of the degree of filiform corrosion EN ISO 4628-10 allows to focus more detailed to the size of filiform corrosion respective blisters. It was possible to recognize average size *L* and maximal size *M* in millimeters. And as it is visible in Fig. 2 evaluation of the same panels, there are characteristics more precise. Fig. 3 shows corrosion progress on sample 3.

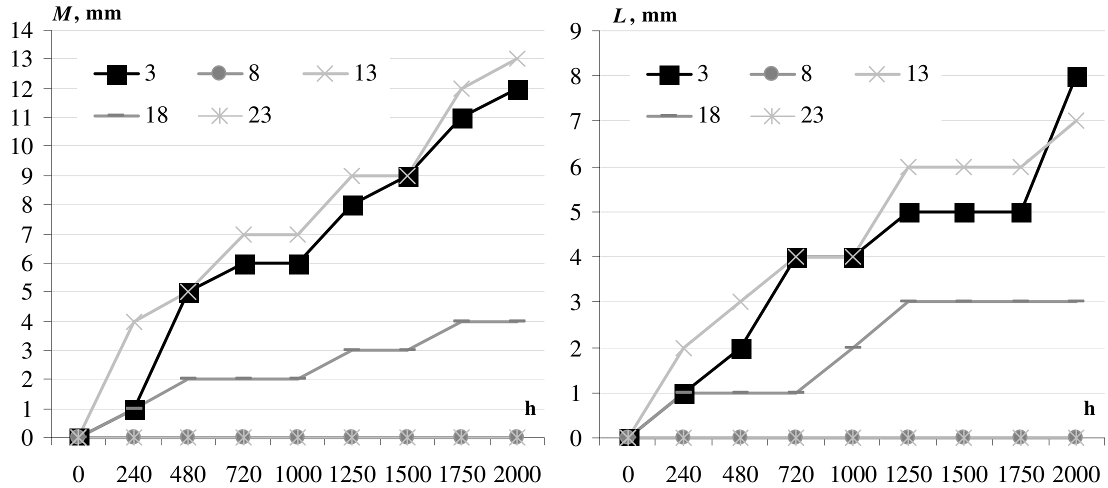

Fig. 2. **Spot welding panels characteristics from degree of filiform corrosion - EN ISO 4627-10**

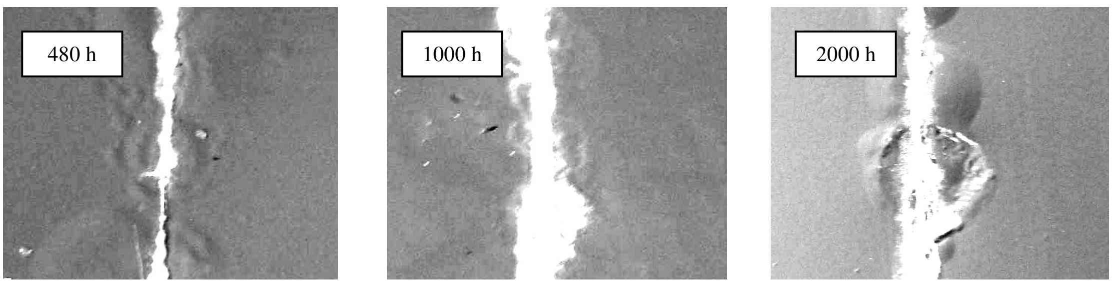

Fig. 3. **Spot welding panels of Sample 3 – observation by 480h, 1000h, 2000h**

2. MAG – welded in protective atmosphere CO_2

Observation of the panels welded by technology MAG in protective atmosphere CO_2 evaluated acc. EN ISO 4627-2 shows analogous characteristics as spot welded as it is visible in Fig. 4. But evaluation of the size of blisters and filifrom corrosion on the same panels acc. EN ISO 4627-10 showed how a more precise method can help.

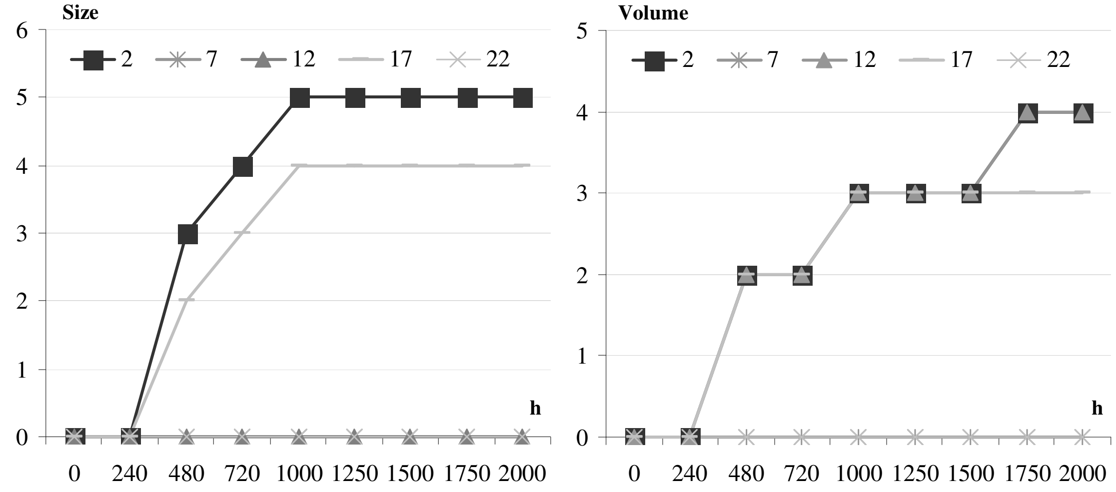

Fig. 4. **MAG welding panels characteristics from degree of blistering according EN ISO 4627-2**

In Fig. 5 it is visible, that although characteristics of spot and MAG welded panels evaluated according to the first method are the same, evaluation acc. to EN ISO 4627-2 has different progress. From this we can say that the three layer system cataphoretic primer + filler + topcoat shows a smaller size level of blistering and corrosion. Fig. 6 shows corrosion progress of sample 2.

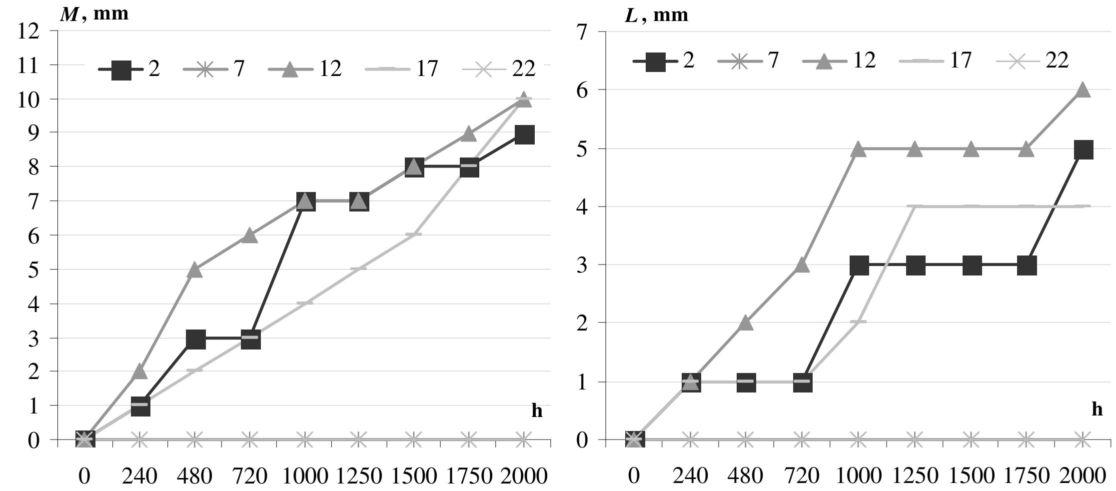

Fig. 5. **MAG welding panels characteristics from degree of filiform corrosion - EN ISO 4627-10**

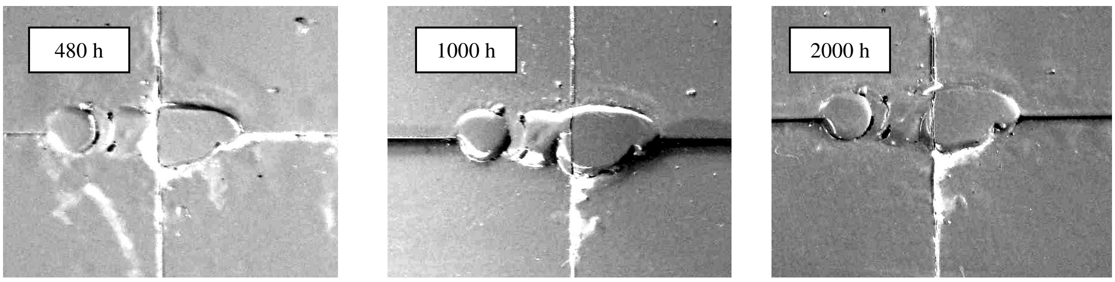

Fig. 6. **Spot welding panels of Sample 2 – observation by 480h, 1000h, 2000h**

3. Painting system (cataphoretic primer + Filler + Topcoat) on different welding technologies

Comparison of the same paining system (cataphoretic primer + filler + Topcoat) on testing panels welded by different welding technologies is expressed in the figures below. In Fig. 7 you can see characteristics from observation according to EN ISO 4627-2. From this you can see, that blistering begins more earlier on spot and MAG welded panels after 240h exposition, then it has nearly the same progress. On not welded panel the first blisters were found after 720h, but after 1250h it was on the same level as for the welded panels. Then to the end of exposition it stayed on the same level. Blistering on panels with a fixed screw and nut was found after 1500h exposition, and it had no other progress and stayed on the same level to the end of exposition.

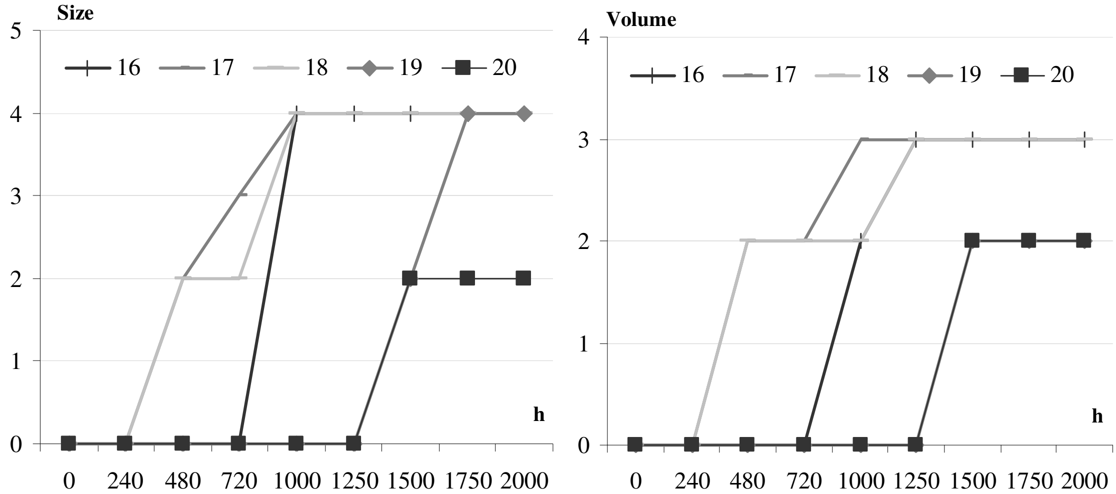

Fig. 7. One painting system on all panels characteristics - according EN ISO 4627-2

Evaluation of the size filiform corrosion acc. EN ISO 4627-10 on the painting system cataphoretic primer + filler + topcoat can be seen in Fig. 8, where there is again more precise visible progress of the size of filiform corrosion. Fig. 9 shows corrosion progress of sample 16.

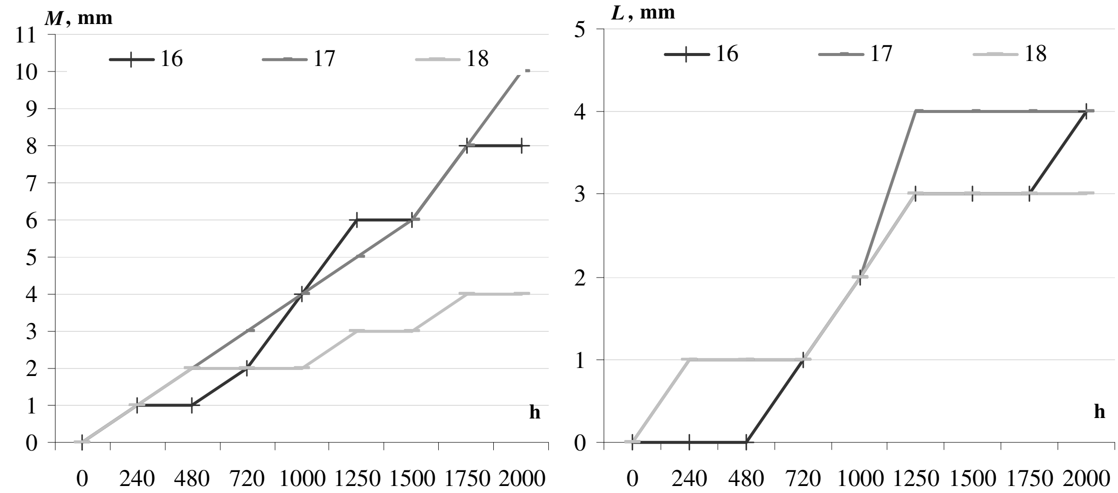

Fig. 8. **One painting system on all panels characteristics – according EN ISO 4627-10**

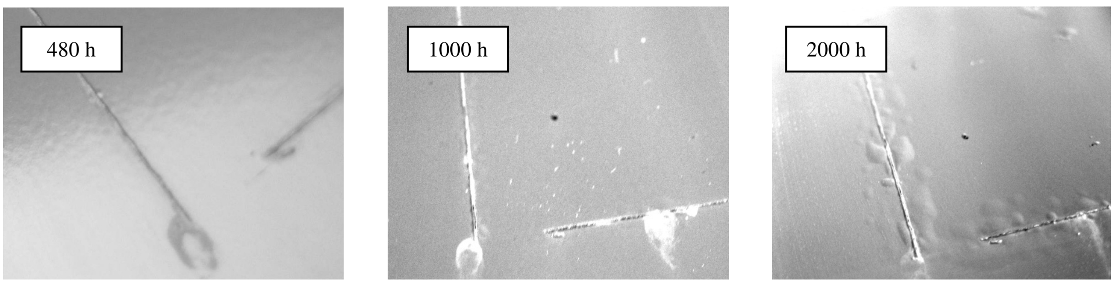

Fig. 9. **Spot welding panels of Sample 16 – observation by 480h, 1000h, 2000h**

Conclusions

On the base of the standards generally usable for evaluations and testing corrosion resistance was updated and new technics of progressive observation improved, which can give us characteristics of corrosion and the blistering process. From all this measuring and observation it is possible to understand the corrosion processes of different painting systems or same painting system on different testing panels welded with different welding technologies in more detail.

Generally, in this case on panels simulated truck cabin from electrolytically zinc coated steel, when we speak about corrosion, we mean white corrosion from zinc layer. Neither 2000h exposition tested panel had corrosion from steel substrate. As the best painting systems were the painting systems used on the bottom of the truck cabin, where plastisol in high film thickness is used, which performs as a very good anticorrosion barrier. As well the painting system used in blank spaces, cataphoretic + wax performs as a very good anticorrosion barrier, mainly due to the fact that wax is permanent liquid and fulfills defects and scribes on the paint layer under. As weak points there are welded joints, from these results we can say, that spot welding has a little bit higher volume of blisters and around spots areas were found bigger blisters than on the panels welded by MAG - welded in protective atmosphere CO2. And these areas can be improved by combination of painting systems with plastisol on not visible connections or waxing in blank spaces. These facts should be taken in consideration during cabin construction.

References

1. García S.J, Suay J., Optimization of deposition voltage of cataphoretic automotive primers assessed by EIS and AC/DC/AC, Progress in Organic Coatings, Elsevier, 2009, pp. 306-313.
2. García S.J, Rodríguez M.T., Izquierdo R., Suay J., Evaluation of cure temperature effects in cataphoretic automotive primers by electrochemical techniques, Progress in Organic Coatings, Elsevier, (November 2007), pp. 303-313.
3. Pierce P.E., J. Coat. Tech. 53, 1981, 52 p.
4. Wernstahl K.M., Carlsson B., J. Coat. Tech. 69 (865), 1997, 69 p.
5. Almeida E., Alves I., Brites C., Fedrizzi L., Prog. Org. Coat. 46, 2003, 8.
6. Suay J.J., Rodriguez M.T, Izquierdo R., Kudama A.H.,. Coat.Tech. 75 (946), 2003, 103.
7. Vatistas N., Prog. Org. Coat. 33, 1998, 14 p.
8. Brewer G.E.F., Hines R.F., J. Paint Tech. 43, 1971, 71 p.
9. Brown W.B., J. Paint Tech. 47, 1975, 43p.
10. Suzuki Y.-I., Fukui H., Tsuchiya K., Arita S., Ogata Y.H., J. Electrochem.Soc. 150, 2003, 251 p.
11. Oravitz J.J., Product Finishing Online, www.pfonline.com, February, 1996,
12. Olivier M.-G., Poelman M., Demuynck M., Petitjean J.-P., Prog. Org. Coat. 52, 2005, 263 p.
13. van Ooij W.J., Zhu D., Stacy M., Seth A., Mugada T., Gandhi J., Puomi P., Tsinghua, Sci. Technol. 10, 2005, 639 p.
14. Bajat JB., Miskovic-Stankovic V.B., Kacarevic-Popovic Z., Corros. Sci. 50, 2008, pp. 2078