DURABILITY OF ANTICORROSIVE PROTECTION COATINGS FOR ELECTRO-ENERGETIC EQUIPMENT

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Abstract - Determining the working life of the anticorrosive protection layers is of great importance for electro-energetic installations. In order to assess the durability of the paint layers have been achieved films of 100 ÷ 120µm from six different commercial types of paint. After polymerization/drying, the dielectric characterization of the obtained films has been achieved by dielectric spectroscopy - both before and after their exposure to controlled doses of UV radiation. The experimental results have been revealed that the polymer matrix of the painting materials, over a critical dose of UV radiation (specific commercial sort), suffers a complex process of aging after which the anticorrosive insulation capacity decreases.

Keywords: painting materials, dielectric spectroscopy, UV radiations, anticorrosive insulation.

1. INTRODUCTION

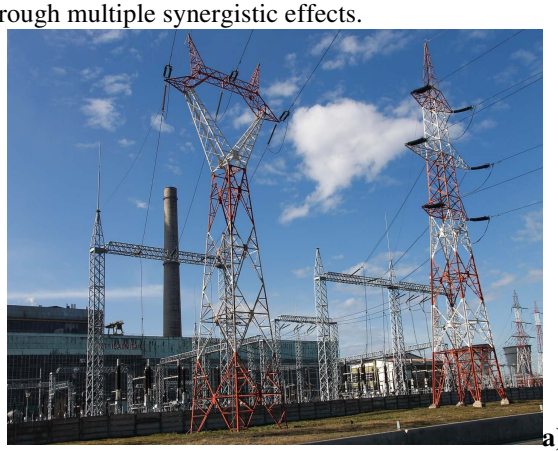
In the view of sustainable development, the issue of safety supply of electricity is very important. Electric power installations and equipment operate in a complex polluted environment, situation where metallic parts and reinforced concrete structures, under the action of specific stress factors, are exposed to several complex processes of degradation by corrosion (Fig. 1) [1].

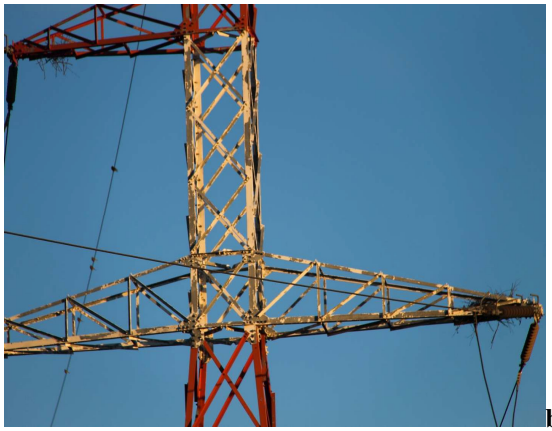
The corrosion of electro-energetic installations has as direct effect reducing the mechanical strength of affected installations. On the other hand, the corrosion products involved by precipitations can be deposited on the insulation systems, which lead to the reduction of their dielectric strength. In these circumstances it is considered that the corrosion is one of the drivers of sustainability and safety in exploitation of the electro-energetic installations [2].

Most electro-energetic installations are exposed to atmospheric corrosion, which can be in open spaces Fig. 1 (a) and (b) or indoor spaces Fig. 1 (c).

The protection against corrosion of the metallic structures exposed to atmospheric corrosion is achieved by coating the exposed surfaces with polymer coatings (paint) [2].

Under practical exploitation, the metallic structure and anticorrosive coatings of the electro-energetic equipment are simultaneously exposed to several stressors that act simultaneously and influence each other through multiple synergistic effects.


a)


b)


c)

Fig. 1. (a) Electro-energetic installations exposed to corrosion in complex polluted environment (b) Installation exposed to atmospheric corrosion in open spaces (c) Electro-energetic installations exposed to atmospheric corrosion in indoor spaces.

The main stress factors which accelerate the degradation of polymeric coatings and hence the atmospheric corrosion of metallic structures in complex polluted environments are:

- *in indoor spaces*:
  - relative air humidity, condensation water;
  - content of air aggressive gases: CO_2, SO_2, NO_x, H_2S etc.;
  - powders / dust (which deposit on wet surfaces and form favorable conditions for development of microorganisms - degradation / micro-biological corrosion [3-5]);
  - electrical stress (electric field generated by the parts that are under voltage, which degrades the paint layers by electrochemical arborescence [6]);
  - mechanical stresses, especially the vibrations which affects the integrity and adhesion of paint layers;
- *in open spaces:*
  - diurnal temperature variations (structural degradation of polymers in paints and mechanical stresses between the metal and coating);
  - precipitations - especially acid rains;
  - frequent freeze / thaw (the humidity, which penetrates the pores of the coatings by freeze, increases its volume - internal mechanical stresses, polymer degradation);
  - solar radiation, particularly UV and IR components - structural degradation of the protection polymer [7-10];
  - content of the aggressive gases (CO_2, SO_2, NO_x, H_2S etc.) and air powders – with humidity creates local corrosion cells;
  - mechanical stresses - mechanical deformations (caused by wind) of the metallic painted structures stress the coatings (pores creating, film cracking, etc.);
  - electrical stress (electric field generated by the parts that are under voltage, which degrades the paint layers by electrochemical treeing.

The qualities of a polymeric film for sustainable anticorrosive protection are:

- good adhesion on the metallic support;
- continuous and homogeneous - without pores and / or cracks;
- high electrical resistivity (blocking of the local corrosion cells);
- impervious to humidity;
- resistant to pollutant gases and atmospheric hazards;
- resistant to solar radiations - especially UV and IR;
- resistant to microbiological degradation, especially to action of filamentous fungi;
- high thermochemical stability - low thermal-oxidability;
- flexibility - the ability to retrieve the mechanical deformations of the metallic support.

Under the concerted and synergetic action of the stress factors, the polymeric support of the paint layers suffers a complex aging process after which the anticorrosive protective qualities diminish substantially.

The operational safety of metallic structures with aged paint layers, can be ensured through proper repainting of them with all economic, social and environmental implications.

As a result of technological developments, on the market, there is a wide range of paints developed for different applications, in which case, selecting the optimum material in terms of technical and economical, both for the protection of new targets and for maintenance (repainting) is required to be made after some tests of accelerated aging by which to assess more accurately, the normal period of exploitation under practical operating data.

Given these considerations, *the aim of the paper* is to assess the exploitation life time of several commercial types of paints exposed to UV radiations.

2. EXPERIMENTALS

In order to assess the exploitation life time of the paint layers, 100 ÷ 120μm films have been made from six different commercial types of paint, namely:

- Sigmaprime 200 [11],
- Sigmacover 456 [12],
- Intergard 410 [13],
- Hardtop [14],
- Interthane 990 [15] and
- Sigmadur 550H [16].

After 10 days of polymerization / drying, the dielectric characterization of the obtained films has been achieved by dielectric spectroscopy at ambient temperature of 23 ± 3^0C (SOLARTRON ANALYTICAL 1296 Dielectric interface / AMTEK), before and after their exposure to UV radiations under controlled conditions: 60W/m^2 at 50 ± 2^0C and relative humidity RH 50 ± 5% (equipment: XENOTEST 440, ATLAS - Material Testing Solutions).

3. EXPERIMENTAL RESULTS AND THEIR INTERPRETATION

Evolutions of dielectric losses - tg δ on the Sigmaprime 200 paint before and after exposure to various UV doses are shown in Fig. 2, of which are revealed that within first 68 hours of exposure to 60 W/m^2 UV, *tg* δ in the investigated material does not change significantly, and at 92 hours of exposure to frequencies higher than 40Hz, *tg* δ increases significantly, which may be due to the polymer degradation.

Table 1 shows the comparative evolutions of dielectric losses - *tg* δ at a frequency of 50Hz for all types of investigated paints.

The analysis of the data from Table 1 has been revealed that at the beginning of UV exposure, *tg* δ decreases, which can be explained by stabilization of the

structure, completion of polymerization and reticulation processes, after which *tg* δ increases, which is due to oxidative and degradation processes by polymer chains cracking because of the higher UV doses. The UV dose at which the polymer degradation processes are initiated, is determined by the type of investigated material, also.

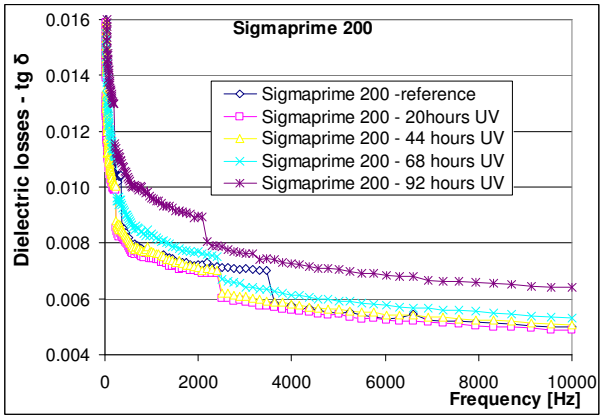


Fig. 2. Evolution of dielectric losses - *tg* δ on Sigmaprime 200 samples

Table 1. Dielectric losses - *tg* δ –at 50Hz of the investigated samples

Sample	Dielectric losses - *tg* δ at UV (60W/m^2) exposure time [hours]				
	0	20	44	68	92
Sigmaprime 200	0.0124	0.0117	0.0112	0.0110	0.0150
Sigmacover 456	0.210	0.112	0.354	0.323	0.314
Sigmadur 550H	0.0784	0.0563	0.0272	0.363	0.0412
Intergard 410	0.0124	0.0123	0.0498	0.0766	0.1011
Hardtop	0.0292	0.0175	0.0317	0.0474	0.0783
Interthane 990	0.0546	0.0504	0.0586	0.0765	0.0976

Based on the data from Table 1, respectively of times after which, to a 60 W/m^2 UV irradiation, the processes of polymer degradation are initiated, can be established a hierarchy of resistance to the UV action of the materials studied thus: Sigmacover 456 > Sigmaprime 200 > Sigmadur 550H > Hardtop > Interthane 990 > Intergard 410.

The capacity of anticorrosive insulation of the paint films, respectively of inactivation of local corrosion cells, is given by the electrical conductivity of the film. Table 2 presents the values resulted from the dielectric spectroscopy measurements of electrical conductivities for the investigated materials.

Table 2. Specific conductivity – σ - at 50Hz of the investigated samples

Sample	Conductivity – σ [10^{-10}·S·m^{-1}] at UV (60W/m^2) exposure time [hours]				
	0	20	44	68	92
Sigmaprime 200	6.21	4.34	3.46	3.34	3.56
Sigmacover 456	33.9	16.0	14.0	13.0	12.5
Sigmadur 550H	11.5	6.66	5.14	4.23	4.12
Intergard 410	6.99	5.97	6.65	7.89	9.92
Hardtop	7.12	5.45	4.60	4.94	9.98
Interthane 990	54.2	48.1	47.2	46.3	58.8

The analysis of the data from Table 2 has been revealed that, during exposure to UV radiations, the conductivity of the investigated samples passes through a minimum, and then, following the structural changes from the polymer, the electrical conductivity of the coating increases which leads to the decreasing of anticorrosive protection capacity. Based on the presented values, two rankings can be established, namely:

- *resistance to UV radiations,* depending on the radiation dose after that is initiated the degradation process: Sigmadur 550H > Sigmacover 456 > Sigmaprime 200 > Interthane 990 > Hardtop > Intergard 410;
- *capacity of anticorrosive protection,* depending on the minimum conductivity value: Sigmaprime 200 > Sigmadur 550H > Hardtop > Intergard 410 > Sigmacover 456 > Sigmacover 456.

Based on the experimental results, cannot be established a direct correlation between the anticorrosive insulation capacity and resistance to UV radiations of the investigated materials. Therefore, for the Intergard 410 material, although it has a low conductivity ($5.97 \cdot 10^{-10}$S/m - high anticorrosive insulation capacity), its resistance to UV radiations is limited - after an exposure of only 20 hours (60W/m^2) the degradation process begins.

Given these considerations, it is found that for metallic structures exposed to atmospheric disturbances and solar radiations, the optimal coatings can be achieved by applying a priming coat with high anticorrosive insulation capacity, over which a finishing layer with high resistance to UV radiations.

In these circumstances, for the investigated materials, *an optimum protection* can be obtained with a priming coat of Sigmaprime 200 (minimum conductivity), then a final layer of Sigmadur 550H (with minimum conductive, at more than 92 hours of 60W/ m^2 UV exposure) is added.

4. CONCLUSIONS

By dielectric spectroscopy measurements have been investigated films made from different types of paints exposed to various doses of UV radiation. After processing the experimental results, it has been found that the polymer of the painting materials, over a critical dose of UV radiation (specific for the commercial type), suffers a complex process of aging after which the anticorrosive insulation capacity decreases. A direct correlation between the value of the critical dose and capacity of anticorrosive insulation (given by the volume conductivity of the material) not been found.

By measurements of dielectric spectroscopy on films made by various types of commercial paints and exposed to various doses of UV can be established the optimal variants of coatings, respectively the selecting of materials for a maximum anticorrosive protection capacity and exploitation life time (proportional to critical dose of UV).

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REFERENCES

[1] Lingvay I., Voina A., Lingvay C., Mateescu C. - The impact of the electromagnetic pollution of the environment on the complex build-up media, Revue Roumaine des Sciences Techniques série Électrotechnique et Énergétique, Tome 53, 2008, no. 2bis, Avril-Juin, ISSN 0035-4066, pp. 95-112.

[2] Rus T., Caramitu A., Mitrea S., Lingvay I. - Comparative study about the thermal stability and UV resistance of some paint layers for electroenergetic equipments, DEMISEE – 2016, IEEExplore – in press

[3] Rus T., Radu E., Lingvay I., Lingvay M., Ciobotea-Barbu O. C., Campureanu C. - Resistance to the action of filamentous fungi's upon some coatings materials**,** U.P.B. Sci. Bull., Series B, 2016. in press

[4] Gnanavel G., Valli V. P. M. J., Thirumarimurugan M. - A Review of Biodegradation of Plastics Waste", International Journal of Pharmaceutical and Chemical Sciences, Vol. 1, Nr. 3, p. 670-673, 2012

[5] Nakajima-Kambe T., Shigeno-Akutsu Y., Nomura N., Onuma F., Nakahara T. - Microbial degradation of polyurethane, polyester polyurethanes and polyether polyurethanes", Appl Microbiol Biotechnol, Vol. 51, p. 134-140, 1999.

[6] Radu I., Acedo M., Filippini J.C., Notingher P.V. and Frutos F. - The Effect of Water Treeing on the Electric Field Distribution of XLPE: Consequences on the Dielectric Strength", in IEEE Transactions on Dielectrics and Electrical Insulation, Vol.7, No. 6, December 2000, pp. 860-868

[7] Awaja F., Pigram J. P. - Surface molecular characterisation of different epoxy resin composites subjected to UV accelerated degradation using XPS and ToF-SIMS, Polymer Degradation and Stability 94 (2009) pp. 651–658

[8] Jianwen H., Xiaogang L., Jin G., Quanlin Z. - UV aging characterization of epoxy varnish coated steel upon exposure to artificial weathering environment, Materials and Design 30 (2009) pp. 1542–1547

[9] Foix D., Ramis X., Serra A., Sangermano M. - UV generation of a multifunctional hyperbranched thermal crosslinker to cure epoxy resins, Polymer 52 (2011) pp. 3269 – 3276

[10] Craciun E., Ioncea A., Jitaru I., Covaliu C., Zaharescu T. - Nano oxides UV protectors for transparent organic coatings *, REV. CHIM. (Bucharest) Vol 62 (1), 2011 pp. 21 – 26*

[11] **** Sigmaprime 200 – https://docs.td.ppgpmc.com//download/428/428/sigmaprime-200-series

[12] **** Sigmacover 456 – https://docs.td.ppgpmc.com//download/456/456/sigmacover-456

[13] **** Intergard 410 – ://www.international-pc.com/PDS/2139-P-eng-A4.pdf

[14] **** Hardtop – http://www.jotun.com/Datasheets/Download?url=%2FTDS%2FTDS__449__Hardtop +AS__Euk__GB.pdf

[15] **** Interthane 990 – http://www.international-pc.com/PDS/2484-P-eng-A4.pdf

[16] **** Sigmadur 550H – https://docs.td.ppgpmc.com//download/339/339/sigmadur-550-h