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Corrosion characterization and protective ability of the LR -3 rust converter

G. M. Raichevski[1], L. Lutov[2], N. S. Boshkov[1*]

[1] *Institute of Physical Chemistry, Bulgarian Academy of Sciences, Acad. G. Bonchev St., building 11, Sofia 1113, Bulgaria*

[2] *University of Sofia, Department of Chemistry, No. 1 James Bourchier St, Sofia, Bulgaria*

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LR-3 rust converter is designed to convert the rust on iron and steel in a non-soluble and stable protecting dark-colored layer. The converter contains organic solvents, mineral acid, complex forming agents and inorganic salts the latter used as active additives for the converting process and distinguished with adsorption-oxidizing properties. The high concentration of organic compounds strongly increases the wetting ability of the converter ensuring better penetration in the finest pores and micro-cracks. This leads to a complete interaction with the rust as well as to a better converting process and excellent adhesion to the metal substrate.

In order to characterize the corrosion resistance of the LR-3 converted layer, it is tested in a model medium of free aerated 0.5M Na_2SO_4. The protective characteristics of the layer are investigated with electrochemical methods, polarization resistance measurements and anodic potentiodynamic curves. Using the optical microscopic method, the thickness and some special features of the appeared converted film are established. A certificate, confirming some physical and functional characteristics of the LR-3 rust converter, is also presented.

This composition stands out as a product of new generation among the other known rust converters, and fully adheres to the modern tendencies. It can find wide application in the agriculture, power-engineering, metallurgy, mining, and in the chemical, military, construction, and transport mine industries, etc. Technological regulations for the production of LR-3 and instructions for its application in real conditions are also prepared.

Keywords: rust converter, corrosion, polarization curves, polarization resistance

INTRODUCTION

Iron and steel are the main materials for construction in almost all technical and technological branches. They are often subject of a corrosion attack in an aggressive media. As a result, their surface is covered with rust, the latter being mainly a mixture of iron oxides and hydroxides in different quantities. The newly appeared corrosion products distinguish in general with a loose structure, and do not fulfill the function of a protective barrier film, aimed to inhibit the corrosion processes in a sufficient degree. For these reasons, the additional treatment of corroding iron surfaces with rust converters is a promising alternative for a better protection.

In most cases this treatment leads to appearance of thin and dense film on the metal surface. This film is resistant against corrosion in liquid and gaseous phases even at wide regions of pH. Nevertheless, this converted layer is not impermeable barrier against metal ions transportation from the film/metal adhesion zone. But yet, this film can inhibit the movement of aggressive ions (the latter provoking the beginning of dissolution or depassivation processes) from the surrounding medium to the metal surface [1–4].

EXPERIMENTAL

The rust converter, used for these investigations, is a multi-component mixture in a liquid phase, the latter consisting of selected organic compounds and negligible water content. Active additives for the rust converting process are some specific inorganic salts with adsorption-oxidizing properties and complex forming agents. The obtained protective film can fulfill two main functions:

- barrier – locks the development of the destructive corrosion processes into the substrate;
- acts as a promising primer for the following polymeric and other organic coatings.

The created rust converted layers are tested with different methods, mainly electrochemical, for example [5–9]:

- Polarization resistance and electrode potential measurements in selected model corrosion media;
- Potentiodynamic polarization curves;
- SEM and optical microscope (cross-sections) studies;

*To whom all correspondence should be sent:
E-mail: nbojkov@ipchp.ipc.bas.bg

- Accelerated investigations at laboratory, model or natural conditions.

2.1. Sample preparation

The corroded samples (working area of 4 cm^2) are initially carefully scraped with a brush to remove the loose part of the rusted layer. Thereafter, they are treated with the LR-3 converter and leaved for several hours. After this time, the rust on the iron surface is converted to high-valent iron oxides and phosphates, both compounds being non-soluble, stable, and forming a dark-colored protecting layer. The organic compounds, present in high concentration in the solution, strongly increase the wetting ability of the converter. This ensures the complete interaction with the rust and leads to excellent adhesion of the converted layer and to metal substrate.

2.2. Polarization resistance (Rp) measurements

The protective ability of the 'iron/converted layer' systems is estimated by polarization resistance (Rp) measurements in the range of +/– 25 mV in relation to the corrosion potential. These investigations are carried out in a three-electrode experimental cell with Luggin-Haber capillary for minimizing the ohmic resistance of the model corrosion medium. Platinum plate is used as a counter electrode while the corrosion potentials are measured with respect to the saturated calomel electrode (SCE). Stern-Geary equation is applied to determine the value of the polarization resistance. As a rule, a higher Rp value corresponds to a higher corrosion resistance and to a lower corrosion rate [10].

2.3. Potentiodynamic polarization curves

Iron samples, covered with rust converted layers or not treated samples were investigated trough potentiodynamic polarization (linear sweep polarization) using PAR Versa Stat equipment at a scan rate of 1 mV/s.

2.4. Microscopic investigations

These investigations are aimed to study the preliminary prepared cross-sections of selected samples, treated with LR-3. The thickness and some specific features, for example extend of the conversion process of the newly appeared protective films, are also established.

2.5. Corrosion medium

A model corrosion medium of free aerated 0.5M Na_2SO_4 solution (pH 6) at ambient temperature of about 20 ºC is used during the investigations.

3. RESULTS AND DISCUSSION

3.1. Polarization resistance

The results concerning the polarization resistance (Rp, Ω.cm^2) of the 'purely' rusty iron samples (non-treated with the LR-3 converter) and the additionally treated samples in a model corrosion medium are presented below:

- Rp value for the rusty iron sample - 185 Ω.cm^2;
- Rp value for the sample with an additionally converted film - 390 Ω.cm^2.

This data contain average results for 5 samples, treated or not treated with the converter, respectively. Similar are the results upon a prolonged test for 6 days in the model medium. The obtained values clearly confirm the better protective characteristics of the converted rusty sample, compared to the non-treated one in the presence of sulfate ions as an aggressive component.

3.2. Potentiodynamic polarization curves

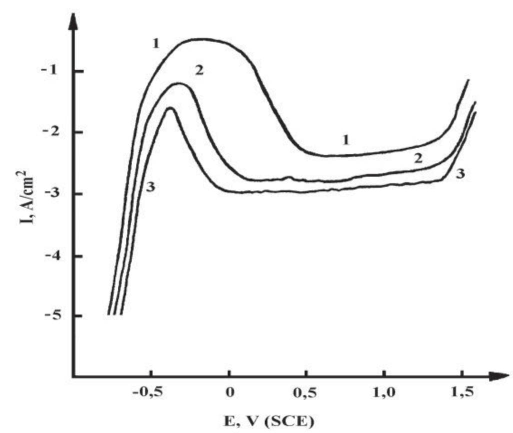


Fig. 1. Anodic potentiodynamic polarization curves of iron samples in 0.5 M Na_2SO_4 solution (scan rate 1 mV/sec): 1 – "clean" iron; 2 – rusty iron; 3 – rusty iron additionally treated with LR-3.

Figure 1 presents the anodic potentiodynamic curves of 3 different sample types. Curve 1 demonstrates the anodic behavior of an iron plate, initially cleaned from rust using an emery cloth, degreased and thereafter anodically polarized.

Curve 2 shows that the presence of rust layer, as a result of the corrosion process, affects, to a certain degree, positively the anodic behavior. This is, for example, the rate hampering of the active dissolution in this medium (barrier effect) which leads to easier passivation. In this case the additional effects are: the shifting of the passivation potential (E_{pass}) to a negative direction with about 350-400 mV, the wider passive zone, and the lower anodic current density. These are very important signs that the rust, appearing on the surface, inhibits, to a certain degree, the penetration of the corrosive medium in depth in direction to the substrate.

In the case when the whole surface is uniformly covered with a compact rust converted layer, the positive effects are clearly expressed (see curve 3): slight shifting of E_{pass} to a negative direction (faster passivation process), wider passive area, compared to the other two samples, and lowest anodic current density value. Additionally, the obtained results demonstrate the increased susceptibility of the converted rusty layers to a passivation under anodic polarization.

3.3. Microscopic investigations

Figure 2 demonstrates a metallographic cross-section image, obtained using an optical microscope. It can be concluded that the rusty layer is of a loose structure, and its adhesion to the substrate is not strong enough.

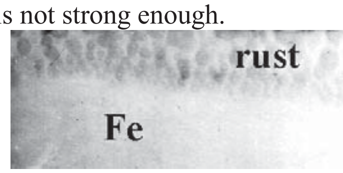
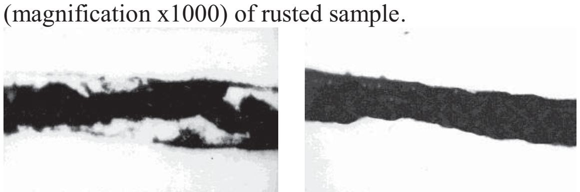


Fig. 2. Metallographic cross-section (magnification x1000) of rusted sample.



(A) **(B)**

Fig. 3. Metallographic cross-sections (magnification x1000) of rusted samples with different extent of rust converting: A – low extent of converting; B – high extent of converting.

In general, this is the reason for the initial (preliminary) mechanical, and in some cases, the electrochemical treatment of the sample. In practical terms, this process is time consuming and needs automation. In all cases, the strong adhesion of the converted layer to the substrate is a very important factor for its protective ability.

Additionally, selected areas with different extent of rust converting are presented in Figure 3. Fig. 3A (left) demonstrates when the conversion process has been partially applied. The black zones are these places where almost the whole rust is converted, ensuring an improved corrosion resistance. White areas are the places where the process is not fully completed and where rusted and converted sections exist at the same time. Figure 3B shows a zone where the converting process is almost complete.

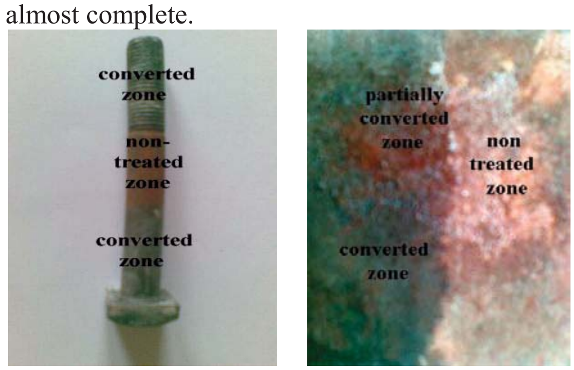


Fig. 4. Images of rusted stud (left) and iron plate (right) after treatment with LR-3.

Figure 4 demonstrates the decorative appearance of some details and their surfaces after the treatment with LR-3. It can be registered that the application of the rust converter leads to some changes in the color. The main result is the disappearing of the rusted areas and the presence of zones with dark color which are the places with the protecting converted layer.

Table 1

No	Parameters	Requirements / Values	Results from the analyses
1	Appearance	Light movable solution	Corresponds
2.	Color	Green	Corresponds
3.	Sense of smell	Acetone	Corresponds
4.	pH value	About 1,5	1,3
5.	Specific weight	0,9 – 1,1	0,97
6.	Time for complete converting of the rust	6 hours	Corresponds
7.	Heat-proof	Up to 150 ^{o}C	Corresponds
8.	Frost-resistance	Up to -40 ^{o}C	Corresponds
9.	Corrosion resistance of the layer in 3% NaCl at 20 ^{o}C	Not less than 10 days without damages	Corresponds
10.	Transition resistance of the layer after converting (Ω/m^2)	More than 1.10^3	2.10^3

3.4. Exemplary Certificate for LR-3

The exemplary Certificate for some physical and functional parameters of the investigated rust converter is presented in Table 1.

4. CONCLUSION

As already mentioned, the received protective film can perform two main functions: 1) to lock the destructive corrosion processes in depth; 2) to act as a promising ground coat for an additional treatment such as painting, coating, etc.

Possessing all these properties, this composition brings an improved corrosion resistance of the treated iron details, and refers to the modern tendencies in the preparation of new rust converter types. It can find wide practical application in different industrial branches. Consumption norm is approximately 50-100 ml/m^2 depending on the rust amount on the corroded metal surface.

The treatment can be done by applying the rust converter with a soft cloth over the surface or by pulverizing. LR-3 can be easily packed in plastic containers of 50 to 100L volume. The containers should be hermetically sealed in order to avoid evaporation of the organic solvents. Dissolution of the inorganic solid substances is done under electro-mechanical stirring. The production process is carried out at 20^{o}C under stirring of the individual components. The addition of each single component is done upon complete dissolution of the previous one. The received solution must stay for 24 h before usage.

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ОХАРАКТЕРИЗИРАНЕ НА КОРОЗИЯТА И ЗАЩИТНИТЕ СВОЙСТВА НА ПРЕОБРАЗУВАТЕЛ НА РЪЖДА LR-3

Г.М. Райчевски[1], Л. Лютов[2], Н.С. Божков[1]

[1)] *Институт по физикохимия, Българска академия на науките, София 1113*
2) Химически факултет, Софийски университет «Св. Климент Охридски», бул. Джеймс Баучер 1, София

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(Резюме)

Ръждопреобразувателят LR-3 е създаден с цел преобразуване на наличната ръжда върху желязо и стомана в неразтворим и стабилен слой с характерен тъмен цвят. Преобразувателят съдържа органични разтворители, минерална киселина, комплексообразуващи агенти и неорганични соли, които са активни добавки в процеса на преобразуване и се отличават с окислително-адсорбционни свойства. Високата концентрация на органични добавки силно повишава омокрящата способност и подобрява проникването и в най-фините пори и микропукнатини. Това води до едно комплексно взаимодействие с ръждата, както и до нейното по-пълно преобразуване и отлична адхезия към металната повърхност.

С цел характеризиране на корозионната устойчивост на обработения с LR-3 слой са проведени изпитания в моделна среда на свободно аериран разтвор на 0.5M Na_2SO_4. Защитните характеристики на ръждопреобразувания слой са оценени с електрохимични методи, измерване на поляризационното съпротивление и анодни потенциодинамични криви. Дебелината и някои особености на новообразувания филм са изследвани с оптичен микроскопичен метод. Представен е и сертификат за някои физични и функционални характеристики на самия ръждопреобразувател.

Новоразработеният състав е от нова генерация продукти и изцяло следва съвременните тенденции. Той може да намери приложение в земеделието, металургията, минното дело, както и в химическата, военната, строителната итранспортната промишлености. Подготвен е технологичен регламент за производството на LR-3, както и инструкции за неговото приложение в реални условия.