CORROSION RESISTANCE OF VACUUM CHROMIZED IRON PARTS FOR HERMETICAL RELAYS

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Abstract: Corrosion resistance of vacuum chromized layers on pure iron to the defined corroding medium of synthetic sea water (3% NaCl solution) was studied. Two different temperatures (25°C and 93°C) and three different times (48, 100 and 200 hours) of testing were used. An attempt was made to define the coating thickness and the content of chromium which will assure optimal corrosion resistance of surface alloys. Chromizing was performed in medium and high vacuum ($3x10^{-2}$ mbar and $2x10^{-5}$ mbar, respectively). Vacuum chromized iron parts (both sintered iron Vacofer S2 and the relay iron ReFe80) with the layer thickness of 70 μm (obtained in high vacuum at $2x10^{-5}$ mbar at the temperature of 1100°C in 12 hours) showed very good corrosion resistance.

Korozijska obstojnost vakuumsko kromanega železa za miniaturne hermetične releje

Ključne besede: releji elektromagnetni, releji hermetični, releji miniaturni, deli sestavni, kromanje vakumsko, lastnosti korozijske, odpornost korozijska, elektronika profesionalna, preskušanje, rezultati eksperimentalni

Povzetek: Študirali smo korozijsko odpornost vakuumsko kromanih plasti na čistem železu proti korozijskem mediju sintetične morske vode (3% raztopina NaCl). Delali smo pri dveh različnih temperaturah (25°C in 93°C) ter pri treh časih (48, 100 in 200 ur). Poskušali smo tudi določiti debelino plasti in vsebnost kroma, ki bi zagotavljala obstojnost površinskih nanosov. Vakuumsko kromanje je potekalo pri srednjem in visokem vakuumu ($3x10^{-2}$ mbar in $2x10^{-5}$ mbar). Zelo dobro korozijsko odpornost so pokazali vakuumsko kromani železni deli, tako tisti iz sintranega železa VACOFER S2 kot tudi tisti iz relejnega železa ReFe80, pri katerih je bila debelina plasti ≈ 70 μm (dobljena v visokem vakuumu $2x10^{-5}$ mbar pri temperaturi 1100°C in času 12 ur).

INTRODUCTION

When studying the properties of vacuum chromized layers (2, 5, 7, 13) on pure iron we found out that they cannot be tested by the methods suitable for the galvanic or chemically deposited layers. An attempt was made to define the coating thickness and the content of chromium which will assure optimal corrosion resistance. Besides, there was the open question of the appropriate method for testing the corrosion resistance (1, 3, 4, 6, 8-12, 14, 15) to the defined corroding medium (16, 17). Vacuum chromized layer on very pure sintered iron VACOFER S2 VACUUMSCHMELZE and the relay iron REFe80 USAB-MUNKFORS were studied.

EXPERIMENTAL

The resistance to attack from salt water is often accepted as a sufficient indication of the corrosion resistance of stainless steel and vacuum chromized iron against the milder and normal atmospheric conditions. This and similar corrosion tests in water and/or different saline solutions are frequently used for stainless and chromized steels. Weight decrease per square cm (mg/sq.cm) and time unit is the measure of the degree of corrosion. Most steels and irons resist corrosion in destiled, river and tap waters while the corrosion in salt water is more severe, since dissolution enhancing the electrolytic effects are predominant. The results give a good indication fairly quickly of the general corrosion resistance of the above mentioned materials. In our investigations corrosion resistance in the defined corroding medium (synthetic sea water (16), often 3% sodium chloride solution) was studied for vacuum chromized test pieces of very pure sintered iron VACOFER S2 (dimensions 50mm x 20mm x 1.2mm) and relay iron REFe80 USAB-MUNKFORS (dimensions 50mm x 20mm x 0.8mm). The test samples were vacuum chromized at the temperature of 1100°C for 3, 6, 9 and 12 hours in a vacuum $3x10^{-2}$ mbar and $2x10^{-5}$ mbar (Table 1). The corrosion test times were 48, 100 and 200 hours at the temperature 93°C. For the vacuum chromized sintered pure iron the weight decrease per square cm is listed in Tables 2, 4 and plotted in Figures 1-4. The corresponding data of the vacuum chromized relay iron are also given in Tables 3, 5 and Figures 1-4.

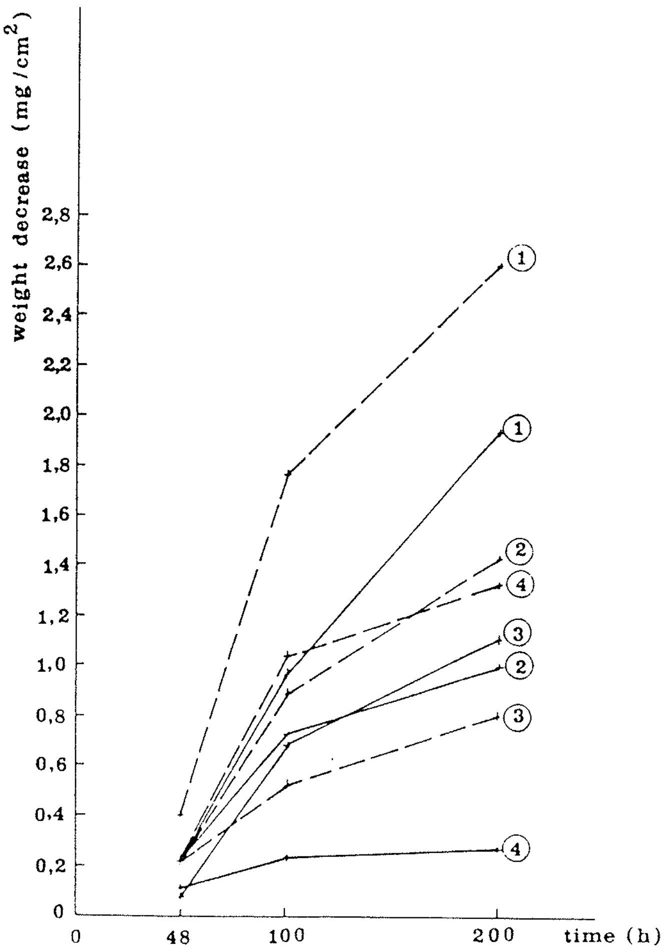

Fig. 1: *Rate of corrosion of vacuum chromized parts ($3x10^{-2}$ mbar, room temperature, 3% NaCl solution)*
________ pure sintered iron VACOFER S2
- - - - relay iron REFe80
1 ,2, 3, 4 types of layers (Table 1)

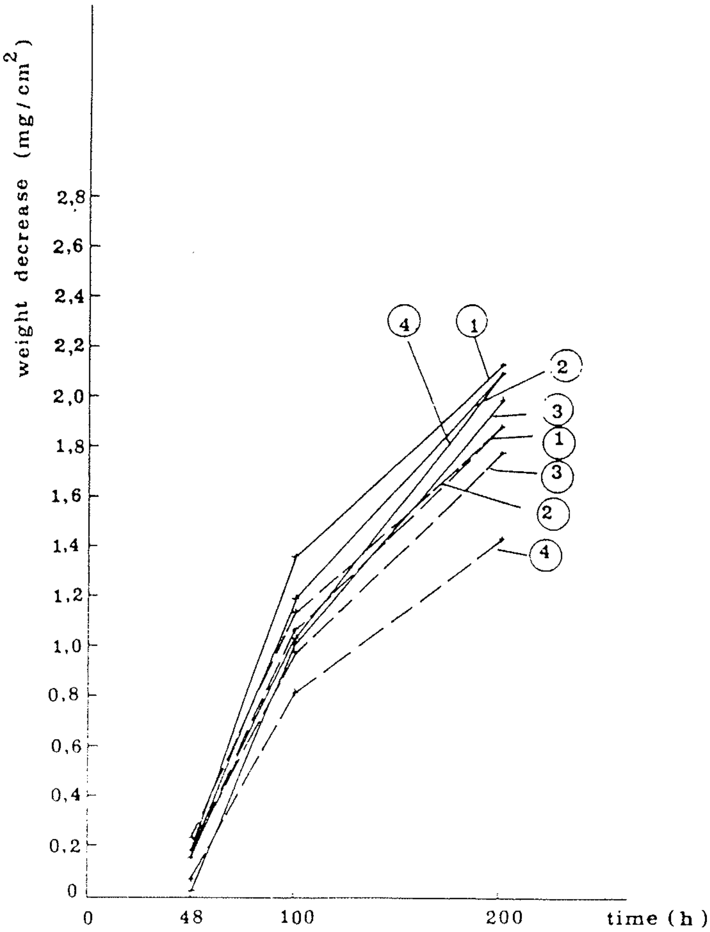

Fig. 2: *Rate of corrosion of vacuum chromized parts ($3x10^{-2}$ mbar, 93° C, 3% NaCl solution)*
________ pure sintered iron VACOFER S2
- - - - relay iron REFe80
1, 2 ,3, 4 types of layers (Table 1)

type of Cr layer	time of chromizing (hours)	pressure (mbars)	thickness (m)
1	3	$3x10^{-2}$	20
2	6	$3x10^{-2}$	34
3	9	$3x10^{-2}$	39
4	12	$3x10^{-2}$	50
1'	3	$2x10^{-5}$	28
2'	6	$2x10^{-5}$	70
3'	9	$3x10^{-5}$	71
4'	12	$2x10^{-5}$	90

Table 1: Parameters of the vacuum chromized parts and the definition of types

type of layer	time (hours) (3% NaCl solution)	weight decrease room temperature	(mg/sq.cm) 93° C
1	48	0.210	0.185
	100	0.985	1.360
	200	1.935	2.130
2	48	0.205	0.175
	100	0.725	1.195
	200	0.995	2.105
3	48	0.080	0.020
	100	0.690	1.015
	200	1.110	1.995
4	48	0.105	0.160
	100	0.235	1.045
	200	0.285	2.100

Table 2: Corrosion of vacuum chromized pure iron VACOFER S2 ($3x10^{-2}$ mbar)

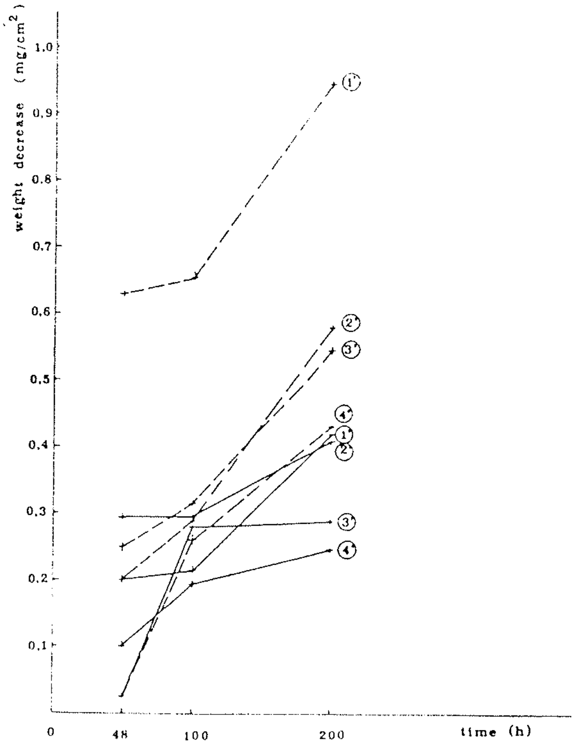

Fig. 3: *Rate of corrosion of vacuum chromized parts ($2x10^{-5}$ mbar, room temperature, 3% NaCl solution)*
________ pure sintered iron VACOFER S2
- - - - relay iron REFe80
1', 2', 3', 4' types of layers (Table 1)

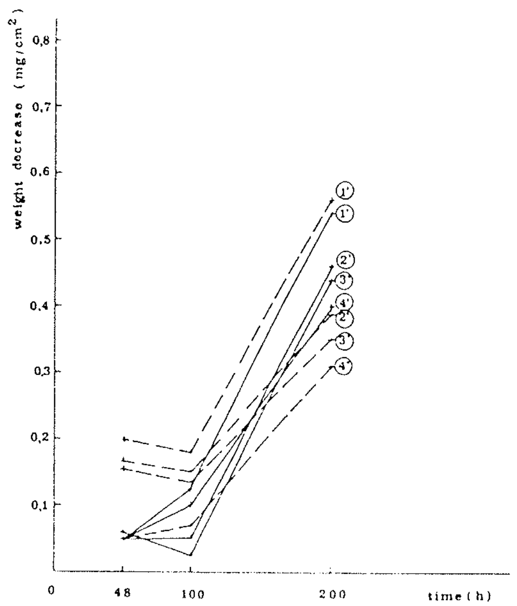

Fig. 4: *Rate of corrosion of vacuum chromized parts ($2x10^{-5}$ mbar, 93^0C, 3% NaCl solution)*
________ pure sintered iron VACOFER S2
- - - - relay iron REFe80
1', 2', 3', 4' types of layers (Table 1)

type of layer	time (hours) (3% NaCl solution)	weight decrease room temperature	(mg/sq.cm) 93° C
1	48	0.405	0.235
	100	1.770	1.155
	200	2.615	1.900
2	48	0.205	0.175
	100	0.890	1.065
	200	1.435	1.885
3	48	0.200	0.200
	100	0.530	0.995
	200	0.795	1.795
4	48	0.205	0.075
	100	1.040	0.815
	200	1.320	1.440

Table 3: Corrosion of vacuum chromized relay iron REFe80 ($3x10^{-2}$ mbars)

type of layer	time (hours) (3% NaCl solution)	weight decrease room temperature	(mg/sq.cm) 93° C
1'	48	0.200	0.050
	100	0.215	0.125
	200	0.420	0.540
2'	48	0.295	0.050
	100	0.295	0.050
	200	0.410	0.460
3'	48	0.050	0.060
	100	0.280	0.025
	200	0.290	0.440
4'	48	0.105	0.085
	100	0.195	0.100
	200	0.245	0.430

Table 4: Corrosion of vacuum chromized pure iron VACOFER S2 ($2x10^{-5}$ mbar)

type of layer	time (hours) (3% NaCl solution)	weight decrease room temperature	(mg/sq.cm) 93° C
1'	48	0.635	0.200
	100	0.655	0.180
	200	0.945	0.565
2'	48	0.200	0.165
	100	0.290	0.150
	200	0.580	0.395
3'	48	0.255	0.155
	100	0.315	0.135
	200	0.545	0.350
4'	48	0.055	0.055
	100	0.260	0.070
	200	0.430	0.310

Table 5: Corrosion of vacuum chromized relay iron REFe80 ($2x10^{-5}$ mbars)

RESULTS AND DISCUSSION

Corrosion of metals in solutions can be described with the laws of electrochemistry. The electrode potentials of metals and ions as well as the pH of aqueous solutions must be known to understand the corrosion processes taking place. When the corrosion properties are in question the vacuum chromized soft iron may be compared with a stainless steel containing 13% content of chromium. The standard electrode potential of this steel is -0.32 eV. In the medium of neutral salt water with a slightly negative electrode potential of iron some various parallel anodic reactions can take place. Iron is ionized into ferri and ferro ions according to the following reactions:

$Fe \text{ -----> } Fe^{3+} + 3e^{-}$ -0.036 V

$Fe \text{ -----> } Fe^{2+} + 2e^{-}$ -0.440 V

$Fe^{2+} \text{ -----> } Fe^{3+} + e^{-}$ -0.771 V

Ferro and ferri hydroxides react with the oxygen dissolved in water giving Fe^{III} hydroxide.

In the neutral salt solution hydrolysis that gives a dilute solution of HCl is obtained which reacts with the ferro ions giving the chloride of bi-valent iron.

$Fe^{2+} + 2\, H_2O \text{ -----> } Fe(OH)_2 + 2\, H^+$

$Fe^{2+} + 2\, HCl \text{ -----> } FeCl_2 + 2\, H^+$

Our experiments undoubtedly show (see Tables 2-5 and Figures 1-4) that vacuum chromized layers obtained in high vacuum on both substrates have better corrosion resistance than the layers obtained in medium vacuum.

CONCLUSIONS

- Strong corrosion effects were found when studying the properties of vacuum chromized layers obtained in medium ($3x10^{-2}$ mbar) and high ($2x10^{-5}$ mbar) vacuum for the layers of type 1 and 1' with the layer thickness of 20 μm and 28 μm, respectively. It is evident that the thickness of these vacuum chromized layers was less than 50 μm.
- Corrosion resistant layers of type 2 and 3 (layer thickness of 34 μm and 39 μm, respectively) obtained in medium vacuum are better but the pitting corrosion was detected at points where profile analysis showed that the concentration of Cr under the surface was less than 13%. The layers of type 2', 3', 4 and 4' with a thickness greater than 50 μm showed excellent corrosion resistance in all mediums both when deposited on very pure sintered iron VACOFER S2 and when deposited on the relay iron REFe80.
- It was shown that for the vacuum chromized corrosion resistant layers obtained in high vacuum $2x10^{-5}$ mbar (layers of types 1', 2', 3' and 4') the thickness was greater than for the layers obtained during the same deposition time in medium vacuum $3x10^{-2}$ mbar (layers of types 1, 2, 3 and 4). The corrosion resistance of the former are therefore better.

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