

LOW CARBON STEELS CORROSION IN DIFFERENT AGGRESSIVE MEDIA

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ABSTRACT. Electrochemical methods have been used to obtain details on the corrosion behaviour of the following carbon steels: OLT – 35, OL 37, OL 44, OL 60 in different electrolytic environments (neutral aqueous solutions, salty, swamp and normal soils). Corrosion parameters of electrochemical reactions at the steel/environment interface as: corrosion potential (E_{corr}) and current density (i_{corr}), was determined using steady state polarization curves method. The results were compared with corrosion rates values obtained by gravimetric measurements. OLT 35 carbon steel was found as the most corroded related to the other studied steels.

Keywords: carbon steel, underground electrochemical corrosion, soil, polarization curves.

1. INTRODUCTION

The corrosion process is quite complexes and depends on the alloy nature and the corrosion environment. From a practical point of view, the underground corrosion of metallic networks is wary important, especially in the presence of the dispersion currents. The simultaneously action of corrosion environment and the dispersion currents bring about much damage on the underground networks [1- 4]. The underground corrosion is the determining factor on the life service of the pipe system. The soil where the pipes are buried has numerous corrosion agents as the oxygen dissolved in water, acid or basic compounds, salts, microorganisms and stray currents [5-6]. The aggressivity of the environment is much enhanced in the soil of the industrialized cyties, where the corrosion processes take place either electrochemically or electrolytically due to stray currents. In the neutral media the corrosion takes place mainly by depolarization with dissolved oxygen.

In order to study the corrosion of gas buried pipes we have taken advantage of recoding the open circuit potential, E_{OCP} .

Low carbon steels OLT-35, that is used at medium and low pressure (up to 60Kgf/cm²) [7-8], has been undertaken for corrosion study and compared with other carbon steels for general usage as OL-37, OL-44, and OL-60.

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2. EXPERIMENTAL

The chemical composition of the studied steels is given in Table1. Eprouvettas of cylindrical or paralelipipedic forms having the area of 1 cm^2 were obtained from carbon steel sorts in the study and used in the corrosion experiments. Before tested, the samples were carefully cleaned mechanically and chemically [9-10]. Various soils, where the gas pipes are buried, as well as salts solutions to simulate natural conditions were employed as electrolytes [11-12]. Their characteristics are contained in table 2.

All potential values were measured and presented in the diagrams as compared to saturated calomel electrode ($E = 0.242 \text{ V}$ versus ENH) as reference.

Table1.

The content of various elements in the alloys

% of	OLT-35	OL-37	OL-44	OL-60
C	0.17	0.22	0.22	0.40
Si	<0.35	0.07	0.50	0.40
Mn	<0.40	0.56	0.95	0.66
P	<0.05	0.055	0.055	0.055
S	<0.05	0.055	0.055	0.055
Fe	Up to 100 %			

In order to record polarization curves, a graphite electrode (made of spectral graphite) was used as counter-electrode. The open circuit electrode potential, E_{OCP} , against time has been measured periodically. The time exposure to the corrosive environment was varied within 0 and 144 hours.

Table 2.

Some characteristics of used electrolytes

Electrolyte	Provenience	pH	Conductivity (mS)
NaCl 1.5%	Laboratory	5.5	12
NaCl 3%	Laboratory	5.5	28
NaCl 1,5% + Na_2SO_4 1,5%	Laboratory	5.5	17
Salty soil	Ocna Dej, salt mine zone	6.7	3.5
Marshy soil	Cluj-Napoca Intre Lacuri district	7.0	10.2
Normal(ordinary) soil	Cluj-Napoca rail station , zone	6.5	0.6

3. RESULTS AND DISCUSSIONS

3.1. Time change of the rest potential (open cell). As literature stipulates, an increase of negative potential in an open cell during time is

associated with metal corrosion, while its positive tendency is associated with a decrease of the corrosion rate or its inhibition by formation of a protecting oxide film at the surface. An oscillating behavior during time is rationalized by a localized corrosion, especially pitting [13].

3.1.1. The effect of chloride on E_{OCP} -time curves. Figures 1.a and b show the E_{OCP} -time diagrams of studied carbon steels in solutions with sodium chloride. For both the concentrations the corrosion process proceeds quite rapidly within the first hours of exposure. In the case of 3% NaCl solution all the samples of OLT-35, OL-37 and OL-44 suffers a steep increase of negative rest potential within the first five hours of exposure. In the case of OLT-35 steel, a change from -505 mV to -635 mV takes place. After that, the change of the potential during time is quite minor. In the case of OL-37 steel after 35 hours a new increase of negative potential is noticed. On the contrary, in the case of OL-60 steel the increase of negative potential is not as steep as for the other two within the first 5 hours of exposure and a slight shift towards positive values. This behavior can be explained by a passivation of this sort of steel.

3.1.2 The effect of sulphate ions on E_{OCP} -time curves. In 1, 5% NaCl and 1, 5% Na_2SO_4 solution a similar pattern of rest potential variation has been found. Within 5 hours an important increase of the negative values has been noticed. In the case of OLT-35 steel, the potential E_{OCP} varied from -521mV to -619mV. After that the change is almost imperceptible. In the case of OLT-35 steel, after 20 hours a slight tendency towards positive value appears (fig. 1.c).

3.1.3 The effect of salt concentration and bacteria content on the corrosion rate. The change of rest potential E_{OCP} during time of the steel samples put in the mud of various soils is presented in figure 2. Within first two hours a similar pattern of dependence was found with ordinary and marshy soil, with a steep increase of negative values. Then, the potential maintains almost constant during time (see figures 2a and 2c)

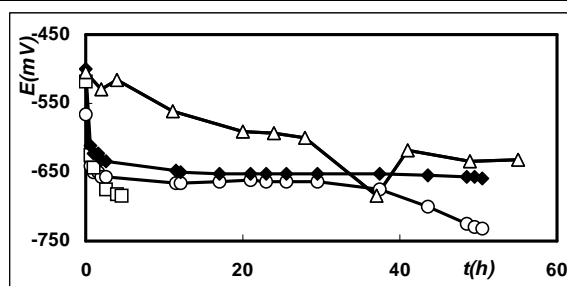
In the case of OLT-35 steel, the salty soil is more aggressive soil exhibiting a continuous increase of negative potential, more pronounced within the first three hours of exposure and a small variation after that. (Figure 2b). When the sample exposure exceeds 28 hours, the rest potential maintains constant, due to passivation. A similar behaviour was noticed with OL-37 steel. When samples were introduced into marshy soil, the negative potential varies less steeply in the beginning period of exposure. After three hours a tendency towards positive values was noticed, indicating some passivation. After 38 hours, the corrosion starts again, due to the destruction of the protective film at the surface [14]. All the sorts of steel exhibit different behaviour in the marshy soil, the passive film at the surface lasts longer than in the salty soil.

Table 3 presents the order of aggressivity of the corrosive tested media on the low carbon steels.

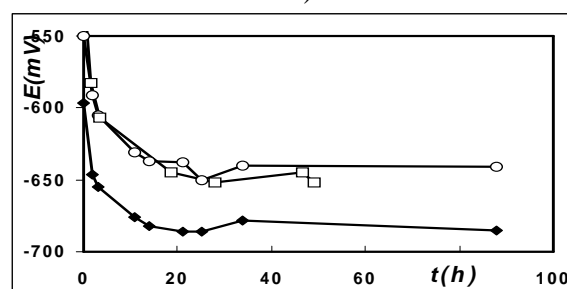
Table 3

Corrosive aggressivity order of used media

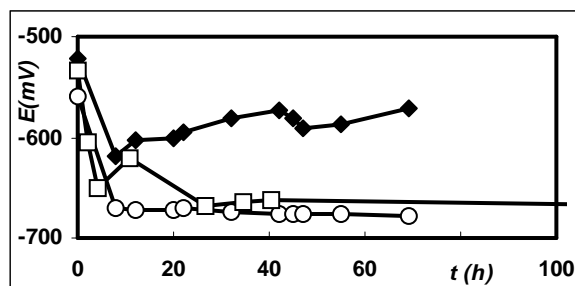
Electrolyte	aggressivity order
NaCl 1.5%	OLT-35 > OL-37 > OL-44 > OL-60
NaCl 3%	OLT-35 > OL-37 > OL-44 > OL-60
NaCl 1,5% and Na ₂ SO ₄ 1,5%	OL-44 > OL-60 > OL-37 > OLT-35
Salty soil	OLT-35 > OL-37 > OL-44 > OL-60
Marshy soil	OL-37 > OLT-35 > OL-60 > OL-44



a)



b)



c)

Fig. 1. E_{0CP} -time diagram for studied steels (---◇--- OL 37; ---□--- OL 44; ---■--- OLT 35; ---△--- OL 60) in: a) NaCl 3%, b) NaCl 1.5%, c) NaCl 1.5% + Na₂SO₄ 1.5% solutions

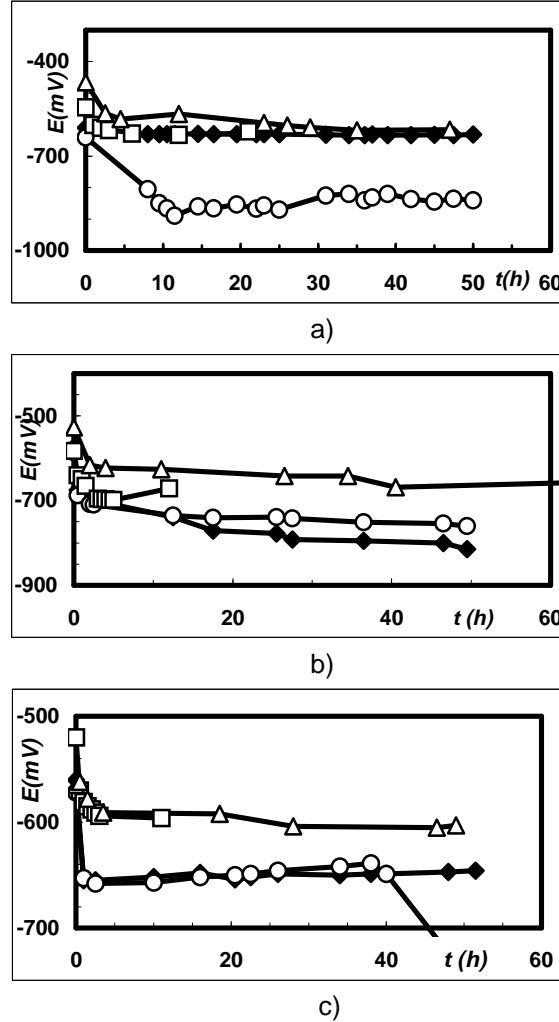


Fig. 2. E_{0CP} -time diagram for studied steels (---◇--- OL 37; ---□--- OL 44 ; ---■--- OLT 35; ---△--- OL 60) in: a) normal(ordinary) soil; b) salty soil c) marshy soil.

3.2. Determination of kinetic parameters. The corrosion mechanism of the various electrolytic media on OLT-35 steel, aiming to determine kinetic parameters of electrochemical surface reactions (corrosion potential (E_{corr}), corrosion current density (i_{corr}) and the corrosion rate) has been obtained from polarization curves [15]. The corrosion current and potential were obtained by the extrapolation of Tafel curves. The corrosion parameters, as obtained from polarization curves are presented in table 4. The gravimetric index, V_{corr} [g/m²h] has been calculated by means of the relationship:

$$v_{\text{corr}} = \frac{i_{\text{corr}} \cdot A}{26,8 \cdot z} \quad (1)$$

where: v_{corr} -the corrosion rate is expressed as gravimetric index, [g/m²h], i_{corr} -stands for the current density [A/m²], z - the number of electrons exchanged in the corrosion process and A stands for the atomic mass of the metal element.

Table 4.
Corrosion parameters

The alloy type	Electrolyte	E_{corr} [mV]	i_{corr} [mA/m ²]	V_{corr} [g/m ² h]
OLT-35	NaCl 3%	-825	870	0.908
	NaCl 1.5%	-790	691	0.721
	Normal (ordinary) soil	-594	301	0.314
	Salty soil	-825	812	0.847
	Marshy soil	-901	933	0.974
OL-37	NaCl 3%	-771	501	0.523
	Normal(ordinary) soil	-660	295	0.307
	Salty soil	-749	805	0.840
	Marshy soil	-813	1000	1.044
OL-44	NaCl 3%	-722	512	0.534
	NaCl 1.5%	-812	436	0.455
	Normal(ordinary)soil	-455	407	0.424
	Salty soil	-800	602	0.628
	Marshy soil	-830	912	0.952
OL-60	NaCl 3%	-843	630	0.657
	NaCl 1.5%	-853	436	0.455
	Normal(ordinary) soil	-583	398	0.415
	Salty soil	-705	810	0.845
	Marshy soil	-763	1112	1.160

The polarization curves for OLT-35 steel in solution are presented in figure 3. The results presented in table 4 shows a decrease of corrosion rate of OLT-35 with the decrease of NaCl concentration and a change of potential towards positive values.

The effect on corrosion of the soils containing salt or bacteria is shown in figure 4. It can be found out that the most aggressive is the marshy soil, having a corrosion rate as much as 3.09 the ordinary soil. The salty soil brings about a

corrosion rate of 1.15 times faster than the ordinary soil. It results from the increase of the mixed corrosion potential towards its negative values.

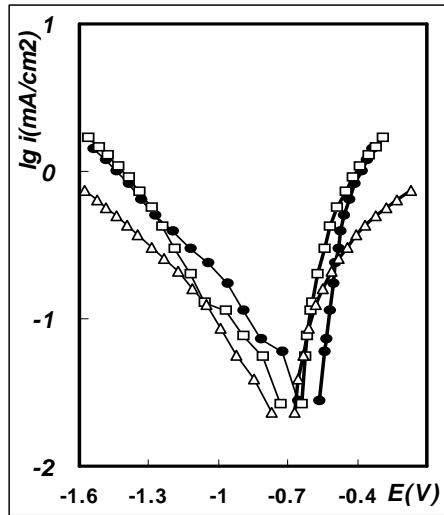


Figure. 3. Polarization curves of OLT-35 in : -□- NaCl 3%; -■- NaCl 1.5%; -△- NaCl 1.5% + Na₂SO₄ 1.5% solutions.

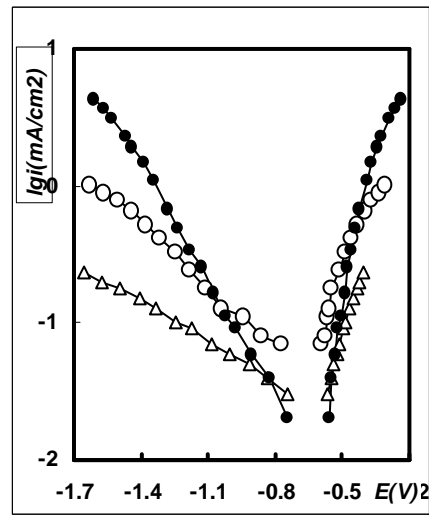


Figure. 4. Polarization curves of OLT-35 -△- normal; -□- salty; -■- marshy soils.

The corrosion rate for the sample buried in salty or marshy soil is comparable or even higher than the one in 3% NaCl solution. Concerning the OLT-35 steel, the order of aggressivity is:

Marshy soil > 3% NaCl solution > salty soil > 1,5% NaCl solution > ordinary soil

From the polarization curves recorded with 3% NaCl for all the steel types undertaken in the study (figure 5) it has been found out the faster corrosion rate in the case of OLT-35.

A comparison of the corrosion rate reveals that OL-37, exhibits a value as 1.73 as the one of OLT-35 in 3% NaCl and comparable with that in the marshy soil. The OL-37 steel exhibits a corrosion rate in marshy soil as much as 1.24 as compared to salty soil, and as much as 3.9 as compared to ordinary soil. For all the steels tested, marshy soil is the most aggressive, followed by salty soil. Always when the corrosion rate decreases, the potential shifts towards positive values. Table 4 reveals also that the OL-44 steel in 3% NaCl solution has a smaller corrosion rate (1.69 times slower) as compared to OLT-35 steel. The

same behavior has been noticed with 1.5 % NaCl solution (Figure 6). The OL-60 alloy has identical corrosion pattern as OL-44 one.

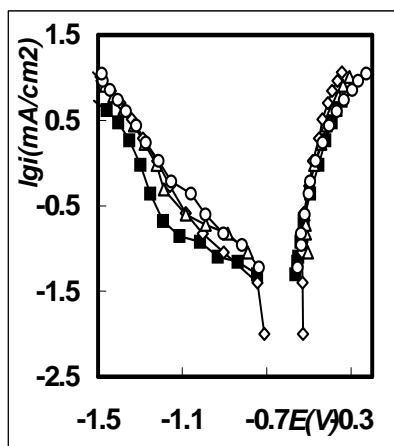


Figure 5. Polarization curves recorded in 3% NaCl solution: --■-- OLT 35; --◇-- OL 37; --□-- OL 44 ; --△-- OL 60.

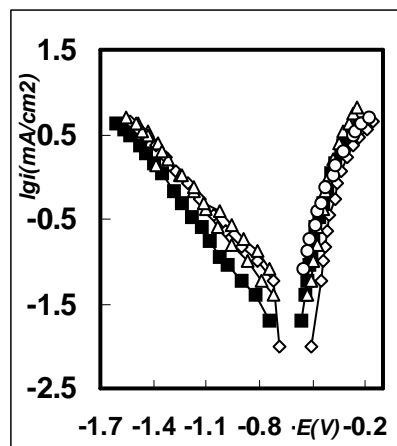


Figure 6. Polarization curves recorded in 1,5% NaCl solution: --■-- OLT 35; --◇-- OL 37; --□-- OL 44 ; --△-- OL 60

CONCLUSIONS

The corrosion rate of OLT-35 steel increases as the salt concentration of the solution increases. The addition of sodium sulphate to 1.5 % NaCl solution has an enhancing effect on corrosion rate of OLT-35. Also, it transforms the generalized corrosion into a localized one during time. The localized and well defined attacks on the alloys were not noticed, the corrosion being mainly uniform with un-adherent and soluble products.

In the cases studied, the tendency of corrosion of OLT-35 is greater than the one of OL-37, with a few exceptions. This behavior is caused by the chemical composition of the two steels (larger content of C, Mn, Si, P of OL-37).

OLT-35 alloy is attacked especially in the salty or marshy soils and less in the ordinary. In the case of OL-37 the corrosion susceptibility is enhanced in marshy soil and ordinary soils.

The corrosion rate is greater when a mixture of salts was used indicating the acceleration character of sodium sulphate. In ordinary soil a smaller corrosion rate has been noticed, as corrosion potential becomes more positive. Because of the generation of corrosive substances by bacteria, all tested alloys were significantly corroded in this sort of soils, even more than the salty soils.

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