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# Corrosion and Scale Control of Carbon Steel in Cooling Waters

Maria Moraru, Alexandra Şchiopescu, Ileana Camenită

Universitatea Petrol – Gaze din Ploieşti, B-dul Bucureşti nr. 39, Ploieşti, România
e-mail: imcamenita@yahoo.com

## Abstract

*This paper presents the experimental researches of corrosion phenomena in cooling waters and relates to the protection of steel surface using some mixtures containing magnesium lignosulphonate, sodium polyphosphate and zinc sulphate as corrosion inhibitors.*

*Electrochemical data and kinetic parameters corrosion steel in cooling waters have been carried out.*

**Key words:** *corrosion, inhibitor, cooling water, magnesium lignosulphonate*

## Introduction

The studies carried out have shown that the cooling waters produce the metallic surface deterioration.

It is known the soluble salts confer a strong corrosive character [1 – 3].

The inside corrosion is accelerated by increase in both the temperature and the oxygen content of the water in the same time.

By the permanent contact between water with atmosphere it is maintained the maximum quantity of oxygen dissolved in recirculation waters, at the saturation limit [4 – 7].

In the same time, due to instability of calcium and magnesium acid carbonates, there appear depositions which are added to corrosion products.

The experimental determination studied the behavior of OLC 45 steel at corrosion in water recirculating cooling systems.

There was studied also the behavior of some compounds or mixtures as corrosion inhibitors in waters such as:

- ○ LGS-Mg – magnesium lignosulphonate,
- ○ LGS-Mg + TPF– magnesium lignosulphonate + tripolyphosphate;
- ○ LGS-Mg + TPF + $ZnSO_4$ – magnesium lignosulphonate + tripolyphosphate + zinc sulphate.

## Experimental Details

The characteristics of waters are presented in table 1.

**Table 1.** Characterization of studied cooling waters

| Corrosive medium | pH | $HCO_3^-$ mg/l | Hardness mval $Ca^{2+}$/l | $Mg^{2+}$ mval $Mg^{2+}$/l | Conduct. µS/cm | TDS ppm | Salinity ppm |
|---|---|---|---|---|---|---|---|
| 1 A | 7.46 | 274.5 | 8.4 | 7.28 | 1300 | 792.7 | 675 |
| 2 A | 7.97 | 274.5 | 9.04 | 8.00 | 1286 | 781.0 | 663 |
| 1 R | 8.04 | 433.1 | 15.2 | 11.04 | 2174 | 1351 | 1176 |
| 2 R | 8.12 | 445.3 | 16.4 | 12.32 | 2264 | 1385 | 1205 |

where: 1 A, 2 A – feed water; 1 R, 2 R - water from the cooler

Experimental determinations were performed in laboratory, using assay-samples made of OLC 45 steel. Chemical composition of tested steel is presented in table 2.

**Table 2.** Chemical composition of OLC 45 steel

| Chemical composition, (%) | | | | | | |
|---|---|---|---|---|---|---|
| C<br>0.48 | Si<br>0.030 | Mn<br>0.79 | S<br>0.025 | P<br>0.020 | Cr<br>0.060 | Ni<br>0.050 |
| Cu<br>0.180 | Mo<br>0.004 | V<br>0.0 | Ti<br>0.001 | Al<br>0.027 | As<br>0.007 | Sn<br>0.012 |

The electrochemical corrosion studies were performed using a „VSP" – Princeton Applied Research laboratory equipment, which represents an assembly potentiostat/galvanostat with multiple functions and software for calculation of electrochemical parameters.

Working electrode had a cylindrical shape with the section area of 1 $cm^2$.

In all cases the electrochemical polarization started after 30 minutes from the electrode immersion in solution, to obtain the stabilization of the stationary potential.

Polarization tests were made in presence of air, in stagnant solutions, at 25°C.

Polarization curves were always registered starting from the stationary potential. By graphic representation of current density in function of the potential of working electrode, there were obtained the anodic and cathodic polarization curves.

In order to reduce ohm resistance we used a single compartment cell, where working electrode was situated in cell center and closed to this, the counter electrode.

By using Evans method and the method of slopes extrapolation, it was determined the rate of the corrosion process, namely it was determined the density of the corrosion current ($i_{cor}$) and polarization resistance (Rp), corrosion potential $E_{cor}$, cover degree (Θ) and the inhibitors efficiency (E.I.).

There were studied the corrosion processes of OLC 45 steel in cooling water with and without LGS-Mg as inhibitor, at concentrations 100 - 500 ppm and the synergist effect of inhibitors mixtures: LGS-Mg, TPF, $ZnSO_4$.

There were drawn the polarization curves of OLC 45 steel at the temperature of 25°C in cooling water 1 A, with and without inhibitors.

## Results and Discussions

Kinetic corrosion parameters which were determined from the polarization curves for OLC 45 steel in cooling water, in presence of the LGS-Mg inhibitor and inhibitors mixtures are presented in table 3**.** The characteristic polarization curves are presented in figure 1 – 4.

**Tabelul 3.** Corrosion kinetic parameters determined from the polarization curves for OLC 45 steel in cooling water, in presence of different synergist inhibitors mixtures

| Conc. inhibitor (ppm) | $i_{cor}$ (μA) | $E_{cor}$ (mV) | Rp (ohm) | ϴ | E.I. (%) |
|---|---|---|---|---|---|
| without inhibitor | 12.984 | - 637.85 | 2009.24 | - | - |
| 100 LGS-Mg | 8.663 | - 628.29 | 3011.35 | 0.333 | 33.28 |
| 500 LGS-Mg | 5.699 | - 615.61 | 4577.75 | 0.561 | 56.11 |
| 500 LGS-Mg +50 TPF | 4.391 | - 708.99 | 5940.51 | 0.662 | 66.18 |
| 500 LGS-Mg +50 TPF+25 $ZnSO_4$ | 3.551 | - 676.59 | 7346.40 | 0.727 | 72.65 |

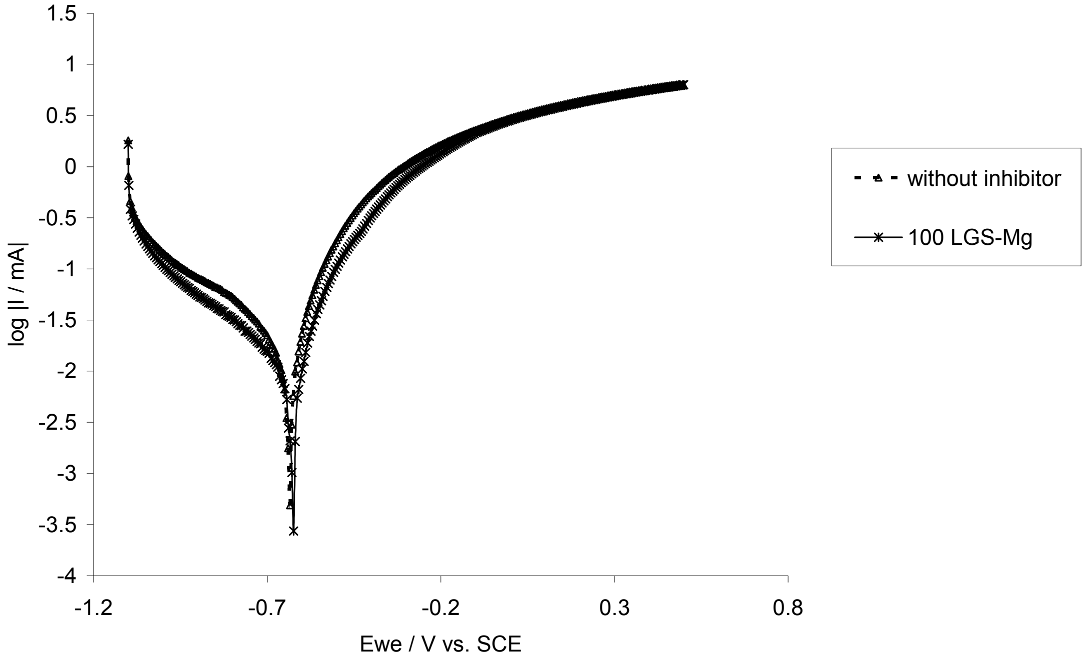

**Fig. 1.** Polarization curves for OLC 45 steel in cooling water with 100 ppm LGS-Mg and cooling water without inhibitor

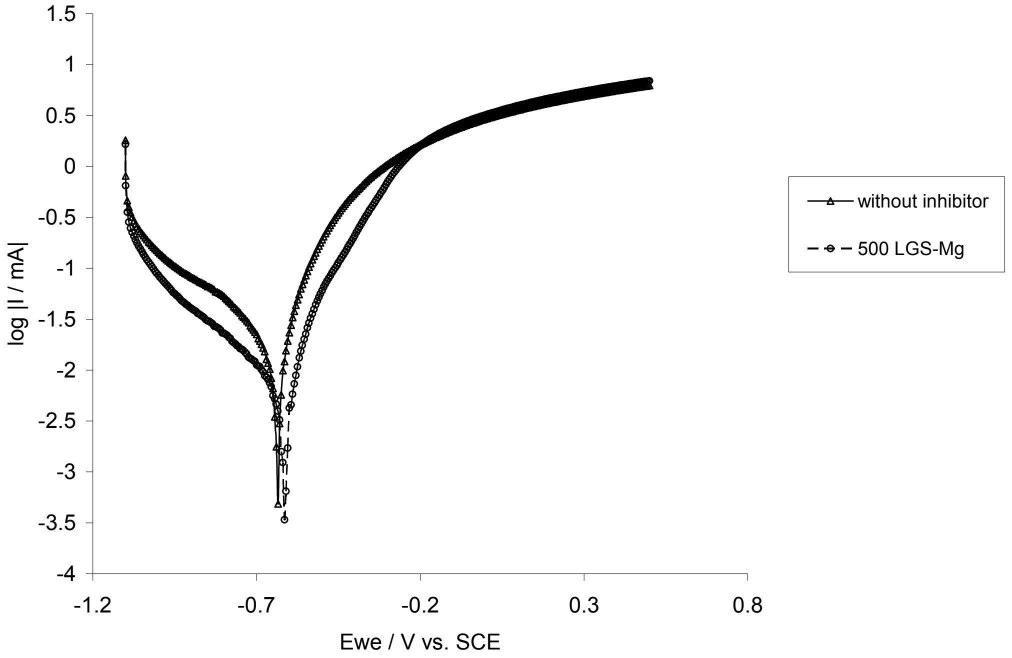

**Fig. 2.** Polarization curves for OLC 45 steel in cooling water with 500 ppm LGS-Mg and cooling water without inhibitor

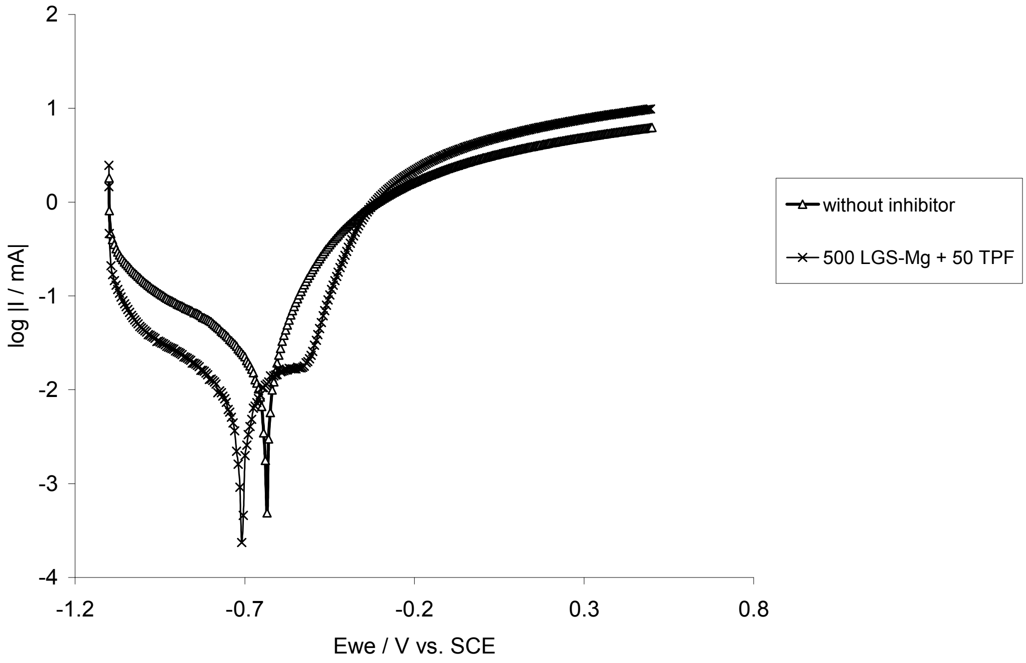

**Fig. 3.** Polarization curves for OLC 45 steel in cooling water with different synergist inhibitors mixtures

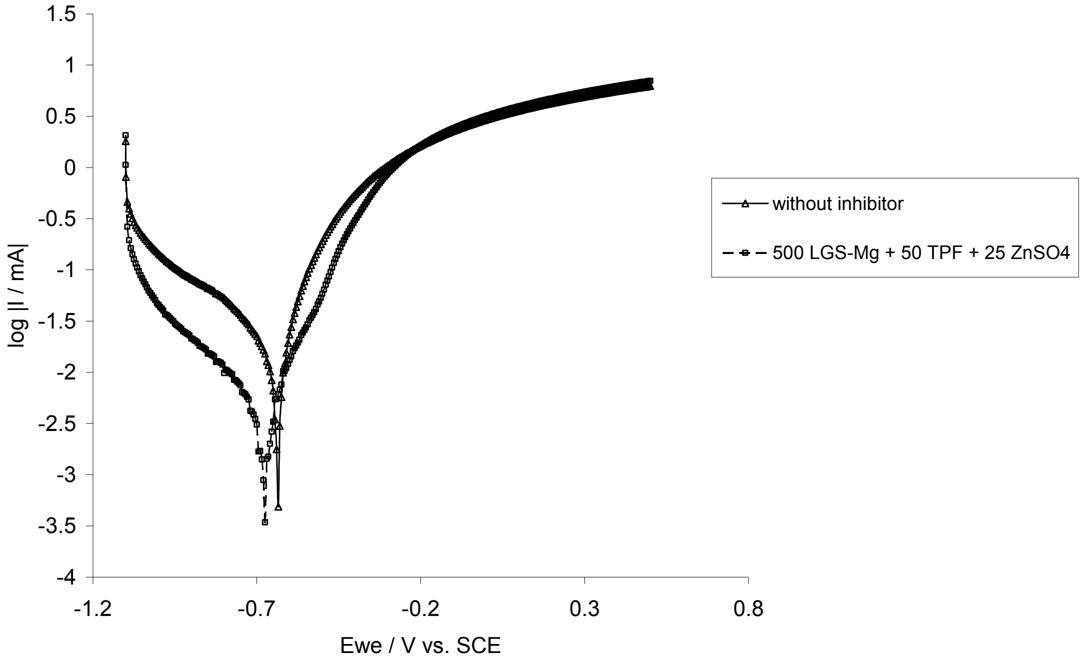

**Fig. 4.** Polarization curves for OLC 45 steel in cooling water with different synergist inhibitors mixtures

## Conclusions

- Tests on corrosion processes of OLC 45 steel in cooling water indicate relatively high corrosion rates.
- By using magnesium lignosulphonate as corrosion inhibitor in cooling waters, an inhibition efficiency of about 56% is obtained at a content of 500 ppm LGS-Mg; because its hydrophile- hydrophobe structure, it leads to the formation of a protection physical barrier at the interface metal/ corrosive medium. Magnesium lignosulphonate presents also dispersant properties, avoiding fouling formation. It is a non toxic product, ecologically tested.
- Sodium tripolyphosphate delays the precipitation process of calcium carbonate, by the complexation in its chain of the crystallization germs and initiates the formation of hard deposits, influencing the increase of the inhibitor efficiency.
- Inhibitor mixtures containing magnesium lignosulphonate, tripolyphosphate and zinc sulphate, by their synergist action in the inhibition process of OLC 45 steel corrosion in cooling waters, present increased efficiencies.
- The components of the inhibitor react with $Ca^{2+}$, $Mg^{2+}$ or even $Fe^{2+}$ions, resulting complexes which form a protecting film on the metal surface which must be protected and stable suspensions because of the dispersant behavior of the polymer. The efficiency of the corrosion inhibition increases from 56% to 72%.
- Mixed inhibitors action as cathodic and anodic inhibitors, in the same time.

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# Coroziunea şi controlul coroziunii oţelului carbon în ape de răcire

## Rezumat

*Lucrarea prezintă cercetările experimentale privind fenomenele de coroziune în apele de răcire cât şi protecţia suprafeţei oţelului utilizând amestecuri ce conţin lignosulfonat de magneziu, polifosfat de sodiu şi sulfat de zinc, ca inhibitori de coroziune.*