The Behavior of Steel Vis-à-Vis the Corrosion in an Aqueous Medium

Rima Harche, Nadia Aicha Laoufi

***Abstract*—**The present work consists of studying the behavior of steel, copper, and aluminum vis-à-vis the corrosion in an aqueous medium in the presence of the antifreeze COOLELF MDX -26 °C. For this, we have studied the influence of the temperature and the different concentrations of the antifreeze on the corrosion of these three metals, this will last for two months by the polarization method and weight loss. In the end, we investigated the samples with the optic microscope to know their surface state. The aim of this work is the protection of contraptions. The use of antifreeze in ordinary water has a high efficiency against steel corrosion, as demonstrated by electrochemical tests (potential monitoring as a function of time and tracing polarization curves). The inhibition rate is greater than 99% for different volume concentrations, ranging from 40% to 60%. The speeds are in turn low in the order of 10-4 mm/year. On the other hand, the addition of antifreeze to ordinary water increases the corrosion potential of steel by more than 400 mV.

***Keywords*—**Corrosion and prevention, steel, copper, aluminum, corrosion inhibitor, anti-cooling.

I. Introduction

In industry, corrosion has considerable economic consequences, both directly, through the intervention costs and the consumption of metallurgical products it generates, and indirectly (shutdown of industrial production units for repairs, degradation of the quality of manufactured products in contact with water loaded with dissolved metals) [1].

Most installations have a cooling section. However, in cooling systems, the corrosion problem arises because of different internal (pH, pressure) and external (environmental aggressiveness) factors [2].

The use of inhibitors as a means of combating corrosion in cooling systems has become essential in recent years. The originality of this method comes from the fact that the anticorrosion treatment is not done on the metal itself, but via the corrosive medium. The use of inhibitors is conditioned by certain parameters such as non-toxicity, efficacy at low concentrations, stability in the presence of other constituents of the medium at the temperature of use [3].

The objective of this work is to evaluate the corrosion behavior of steel, copper and aluminum in a medium consisting of ordinary water and antifreeze TOTAL COOLELF MDX -26 °C. The latter plays the role of antifreeze and organic corrosion inhibitor; it is used to combat the corrosion problem within cooling systems [4].

II. Experimental Study

During this study, we used an assembly that allows us to fix the working conditions and to get closer to the conditions of use of antifreeze and metals in question. The assembly used is shown in Fig. 1 and comprises:

1. Potentiostat-galvanostat PGZ301 type Radiometer, associated with the software «voltamaster 4».
2. Electrochemical cell: For electrochemical tests, we used a cylindrical pyrex cell with a capacity of 150 mL. It is equipped with a double wall for temperature regulation, via a thermostatic bath.

- Working temperatures are 20 °C, 40 °C and 60 °C.
- The cell is equipped with a pyrex cover.
- A working electrode, consisting of one of the metals coated in a resin, allows to delimit the surface.

3. Magnetic stirrer: It ensures moderate agitation during the tracing of potential as a function of time and potentiodynamics using a magnetic bar.
4. Study medium (electrolyte): The corrosive medium studied is tap water (ordinary) to which antifreeze (TOTAL COOLELF MDX -26 °C) is added at different volume concentrations (40%, 50% and 60%).

Infrared spectroscopy analysis of this antifreeze showed the existence of the following functions: -OH, $-NH_2$, -N=C=O, C-C(O)-C,C-I,C-Br.

Fig. 1 Diagram of the measurement chain

A. Preparation of Samples

The samples used are parts of the metal to be studied of rectangular shape of dimension (50 x 15 x 1), before immersion of each part in the solution, the surface to be exposed to the test is subjected to mechanical stripping with sandpaper of grain

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size 600, followed by degreasing in a surfactant solution, the sample is then washed with water, dried and then covered with an insulating layer of varnish that limits the working surface.

III. Results and Discussions

A. Evolution of Abandonment Potential

The monitoring of potential as a function of time makes it possible to record changes in the interface between the material and the surrounding environment. The evolution of the free potential of steel in ordinary water in the absence and presence of antifreeze at different volume concentrations is shown in Fig. 2.

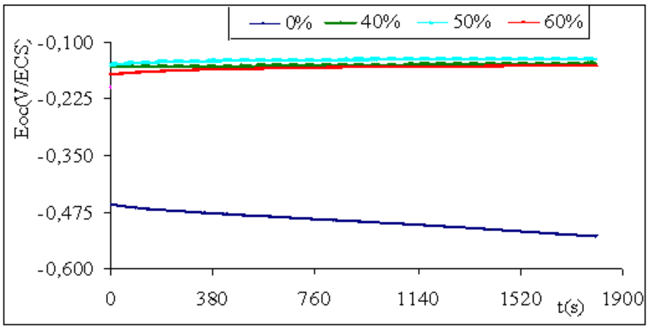

Fig. 2 Evolution of the potential in open circuit for steel immersed in ordinary water in the absence and presence of antifreeze a 20 °C

The presence of antifreeze at density concentrations 40%,50% and 60% in ordinary water results in the ennoblement of the free potential of steel. The potential value stabilizes around -146 mV, -135 mV and -152 mV for the previous volume concentrations respectively compared to -530 mV in the absence of antifreeze. This displacement would be the consequence of the delay of the anodic reaction of iron dissolution due to the action of the product [5].

B. Evolution Over Time of Corrosion Potential and Decorrosion Current Density

Figs. 3 and 4 illustrate the influence of immersion time on the corrosion potential and corrosion current density of steel in ordinary water in the presence of antifreeze. These values are taken from the plots of the polarization curves for different immersion times up to 45 days.

According to Fig. 3, the corrosion potential of steel in the presence of antifreeze at different concentrations by volume varies with immersion time in an irregular manner, unstable from day 1 to day 16 and stable between 20 and 40 days.

In general, during the 40 days, the corrosion potential of the steel in the presence of antifreeze remains more noble compared to the corrosion potential of the steel in water alone which turns around -700 mV.

According to Fig.4, the stability of the corrosion current density is marked after 15 days of immersion for all antifreeze concentrations, nevertheless after 40 days the corrosion current density increases with the immersion time for 50% and 60% antifreeze concentrations.

Despite the variation of the corrosion current density with the immersion time, it remains about 10 $^{-8}$A/cm² during the sixty days of immersion, which allows us to say that the corrosion is negligible.

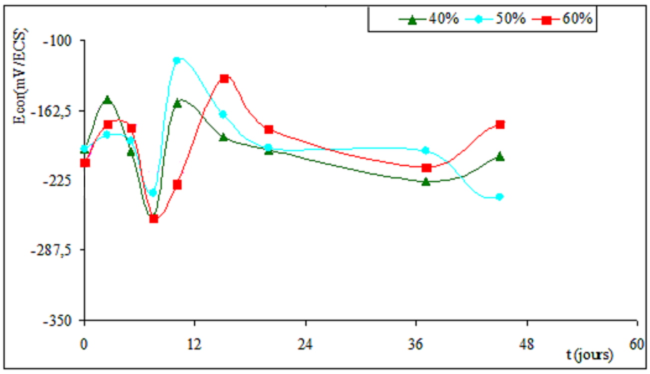

Fig. 3 Ecor evolution over time for steel in ordinary water in the presence of different antifreeze concentrations by volume at 20 °C

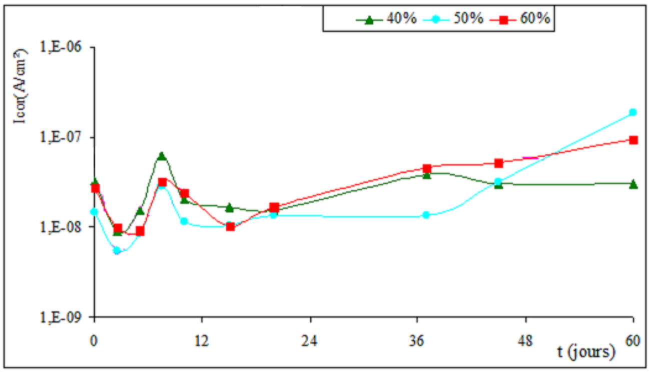

Fig. 4 The evolution over time of Icor for steel in ordinary water in the presence of antifreeze at different concentrations at 20 °C

C. Polarization Curves

Fig. 5 shows the polarization curves for steel in ordinary water in the absence and presence of antifreeze at different volume concentrations (40%, 50% and 60%).

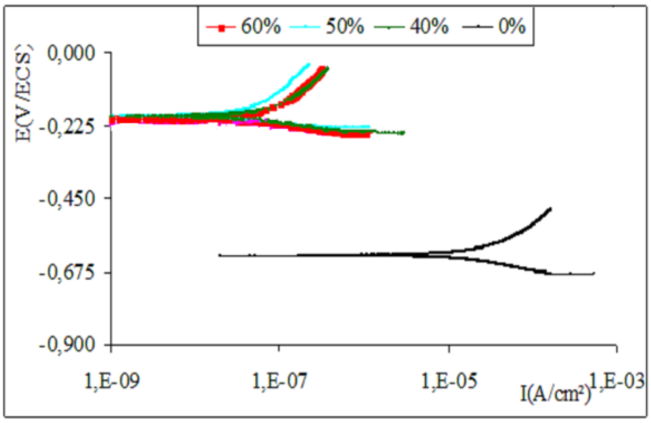

Fig. 5 Polarization curve for steel in ordinary water in the absence and presence of antifreeze at different volume concentrations at immersion at 20 °C

According to Fig. 5, the corrosion potential of steel is rapidly elevated in the presence of antifreeze. It increases by 400 mV compared to that of steel in ordinary water alone. On the other hand, it appears on the figure that the presence of antifreeze in ordinary water induces a general lowering of corrosion current densities. This decrease is about 1000 times compared to that obtained in ordinary water alone. In this case corrosion is considered negligible.

The values of some electrochemical parameters Ecor, Icor and the anodic and cathodic slopes and the corrosion rate and the inhibition rate are given in Table I.

TABLE I
VALUES OF SOME ELECTROCHEMICAL PARAMETERS

Volumetric concentration	E_{cor} (mV/ECS)	I_{cor} (A/cm²)	B_c (mV/)	B_a (mV/)	Vcor (mm/an)	θ (%)
0%	-583	$1,10.10^{-5}$	-53	167	$1,27.\ 10^{-1}$	--
40%	-197	$3,219.10^{-8}$	-38	85	$3,75.10^{-4}$	99,70
50%	-197	$1,459.10^{-8}$	-29	66	$1,7010^{-4}$	99,87
60%	-208	$2,693.10^{-8}$	-34	49	$3,13.10^{-4}$	99,75

It is known that there is a linearity between the corrosion current density and the corrosion rate, but knowledge of the corrosion rate is a practical way to properly assess corrosion. And for this purpose, the values of the corrosion rates given in Table I vary between $1.70.10^{-4}$ and $3.7.10^{-4}$ mm/year in the presence of antifreeze. These values are very low compared to the value of corrosion rate in water alone.

D.Study of the Effect of Temperature

The effect of temperature on corrosion kinetics can help to understand the mode of action of inhibitors and the mechanisms involved. Most chemical and electrochemical reactions become faster when the temperature rises.

In our work, the study of the effect of temperature is necessary because this parameter is related to the conditions of use of this antifreeze.

Fig. 6 shows the polarization curves obtained for steel in water in the presence of antifreeze at 50% volume concentration for temperatures 20 °C, 40 °C and 60 °C.

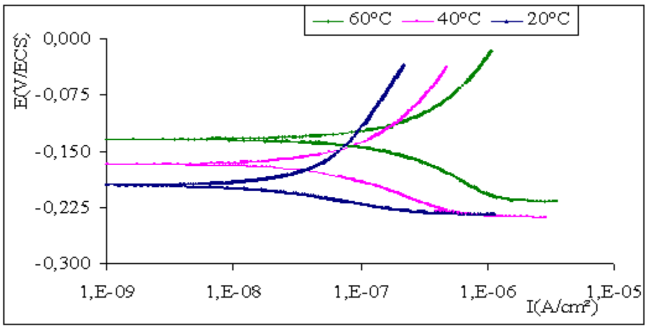

Fig. 6 Polarization curve for steel at temperatures 20 °C, 40 °C and 60 °C in ordinary water in the presence of antifreeze at a volume concentration of 50%

The increase in the temperature of ordinary water in the presence of antifreeze to 50% by volume induces a corrosion potential enhancement of 60 mV between 20 °C and 60 °C and an increase in the corrosion current density of $1.459.\ 10^{-8}$ A/cm² for 20 °C to $1,145.10^{-7}$ A/cm² for 60 °C that is, the corrosion rate increases. Thus, the increase of the temperature of the medium induces an ennoblement of the corrosion potential of the steel and an increase of the corrosion current density.

In the presence of antifreeze at different concentrations, the temperature acts in the same way, however the increase in the temperature of ordinary water in the absence of antifreeze causes a decrease in the corrosion potential as shown in Fig. 6.

E. Loss of mass

Fig.7 shows the evolution of the mass of the steel parts each immersed in ordinary water in the absence and presence of the different density concentrations of antifreeze.

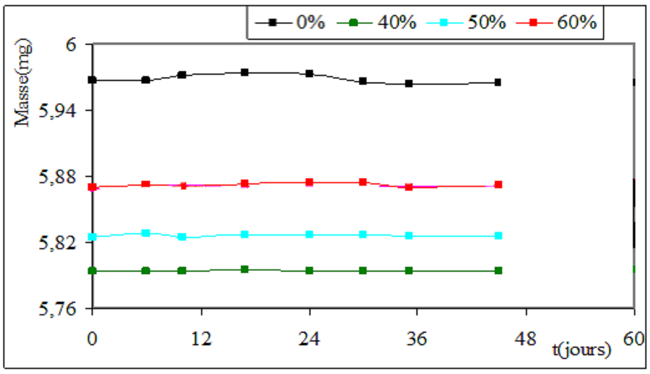

Fig. 7 The evolution of the masses of the steel parts each immersed in ordinary water in the absence and presence of the different concentrations of antifreeze

The data for the change in mass as a function of immersion time at 20 °C are shown in Fig. 7. The masses of the steel parts immersed in ordinary water in the presence of antifreeze at different concentrations remain constant during the sixty days, indicating that the steel has not undergone any attack. On the other hand, in ordinary water only it is found that the mass registers a growth from 7th day which implies that the steel corrodes in the absence of antifreeze. This finding allows to say that the antifreeze ensures a good protection of the steel vis-à-vis the corrosion.

IV. CONCLUSION

This work aims to evaluate the inhibitory power of an antifreeze, vis-à-vis the corrosion of the steel; this antifreeze is intended to lower the freezing temperature of the water in the cooling circuits.

This study was conducted over 45 days by monitoring the corrosion potential and corrosion current over time at different temperatures (20 °C, 40 °C and 60 °C), it is supplemented by a monitoring of the mass loss by weighing and by metallographic examinations of the surface of the samples studied. This study brought us back to the following conclusions:

The effectiveness of antifreeze added to ordinary water against steel corrosion was confirmed by electrochemical tests (potential monitoring as a function of time and tracing of polarization curves).

The inhibition rate reaches 99% for different volume concentrations, ranging from 40% to 60%. The speeds are in turn low in the order of 10^{-4} mm/year.

The temperature influences the electrochemical parameters regularly. It causes a decrease in the corrosion potential of the steel and a slight increase in the corrosion rate.

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