Nonconventional Technologies Review
Romania, September, 2015

CORROSION STUDIES ON OL 37 STEEL USED FOR HOT WATER PIPES, IN DYNAMIC CONDITIONS

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ABSTRACT.Corrosion and corrosion protection of steel pipes corrosion, in the field of transportation and distribution urban water grids is a particularly important economic factor in loss prevention, combating environmental pollution and economy. The corrosion rate of a metallic material depends on a number of factors such as the nature of the metal structure and the surface condition of the metal, the composition of the electrolyte (pH, dissolved oxygen content, the presence in the solution of corrosion inhibitors or accelerators), temperature, pressure, flow rate of the solution. Determination of the corrosion rate of OL37 carbon steel was achieved in synthetic hot water, using the weight loss method, in laboratory static and dynamic conditions.

KEY WORDS: corrosion, urban hot water network, steel pipes, dynamic conditions

1. INTRODUCTION

The natural and spontaneous phenomenon of metals corrosion can’t be eliminated in totality but it can be controlled, by corrosion management. Many researchers have added their contribution to the knowledge of a better management of the hot water urban networks made by steel pipes.

Sometimes is rather better to apply a simple method of corrosion prevention, based on application of accumulated knowledge. From the sustainable development’s perspective, energy efficiency must be seen more than its engineering definition, but as a more comprehensive, interdisciplinary concept, including also sociological and philosophical aspects. That means not only science and technology understanding [1], but also good policies, education and responsibility, for both human life and environment.

Water transportation network have been and still is an interesting scientific issue for all the urban areas: water is not the most important for us as beings, but for our developing societies.

Each system is different, this is why is important that every urban water network should be study by its particularity [2-4], based on the physico-chemical properties of water, soil , air, materials, weather conditions also combined with modern approaches, mathematical and statistical modeling [5].

Applying corrosion prevention methods, as corrosion and scaling inhibitors [6-9], platings [10], cathodic protection, materials studies[11], rigorous application of codes and regulations, chemical studies on water composition [12], creating databases [10], operational reability studies [11, 13] and failure analysis [14], analyse of risk and incorrect decision[10], are all ways to avoid corrosion damage.

Corrosion causes direct material losses but might due to many accidents and disasters: starting with water leakage from pipes of the heat distribution networks or water supply networks. Cracked pipes allow water to enter the soil, and leads to water lenses formation. These could produce flooding in foundations and threat the buildings. Water leaks could affect roads, which are dug to repair the pipes.

2. EXPERIMENTAL

The weight loss studies on the OL 37 carbon steel were performed in synthetic water with similar composition as the heating water from the urban water transportation network in static and dynamic conditions. The synthetic waters were prepared from chemically of Merck purity and double distilled water. The experiments were carried out at constant temperatures of 20^oC and 80^oC, at the atmospheric pressure in open system.

The corrosion rate of carbon steel in synthetic hot water was determined gravimetrically in dynamic conditions. Four parallel samples were exposed in a glass cell, which allowed the measurement of corrosion potential versus time of exposure. The cell was connected to a thermostat and water was circulated with two speeds: 0.6 L/min. and 2.4 L/min. A flashing program was used, consisting of 12-hour heating and maintaining the flow of water through the plant and within 12 hours the samples were exposed to room temperature (20°C) without water circulation.

The exposure time of the samples in the corrosion has varied from 2 to 14 days. Removal of corrosion products from the samples was done by wiping them with a solution of ammonium citrate (10%) and ammonia, and in the case of most grip by means of a spatula (made of wood sticks), followed by washing with water and acetone. The corrosion rate was calculated by the relationship [2]:

$$v_{cor} = \frac{\Delta G}{S \cdot t}, \text{ [g/m}^2\text{h]} \qquad (1)$$

in which: ΔG is the loss in weight as a result of exposure to corrosion, in g; S - the surface area exposed to corrosion, in m^2 and t – time of corrosion exposure , in hours.

Penetration index or corrosion rate expressed in mm/year, is calculated with the relation :

$$P = \frac{v_{cor} \cdot 8760}{1000 \cdot \rho}, \text{ [mm/year]} \qquad (2)$$

where, ρ is the density of the metal to corrode, in g/cm^3, 8760 is the hours number from a year and 1000 is a correction factor [2].

The efficiency [2] of the inhibitor protective action was calculated with the relationship:

$$\%P = \frac{v_{cor,0} - v_{cor,i}}{v_{cor,0}} 100 \qquad (3)$$

where: $v_{cor,0}$ is the corrosion rate in the absence of the inhibitor and $v_{cor,I}$ is the corrosion rate in the presence of the inhibitor.

3. RESULTS AND DISCUSSION

Because the district heating water temperature can vary during the year, for various reasons, we chose to study a temperature range between 20°C÷80°C, In dynamic conditions the carbon steel corrosion rates in hot water are 4-5 times higher than in static conditions as shown in table 1.

Table 1. The corrosion rate of OL 37 in hot water, according to the working regime , at temperature of 20°C and an water flow rate of 0.6 L/min.

Exposure time, days	Corrosion rate, mm/year	
	Static conditions	Dynamic conditions
2	0,0668	0,2950
4	0,0562	0,2471
6	0,0485	0,1959
8	0,0472	0,1510

Under static conditions the carbon steel corrosion can be combated effectively running water binary mixtures of phosphate and sodium hexametaphosphate. It has been reported that a mixture having the composition: 0.1 g/L disodium phosphate and 0.25 g/L of hexametaphosphate resulted in a corrosion rate of only 0.0009 mm/year, and an inhibitor efficiency of the protection is the 98.63%. In this study we tested the effectiveness of inhibition of this mixture under dynamic conditions and seek for an higher corrosion protection action by increasing the inhibitors concentration and addition of calcium ions.

Figure 1 shows the dependence of the corrosion rate of OL37 carbon steel on water flow and temperature in the presence of the binary mixture: 0.1 g/L disodium phosphate and 0.25 g/L hexametaphosphate.

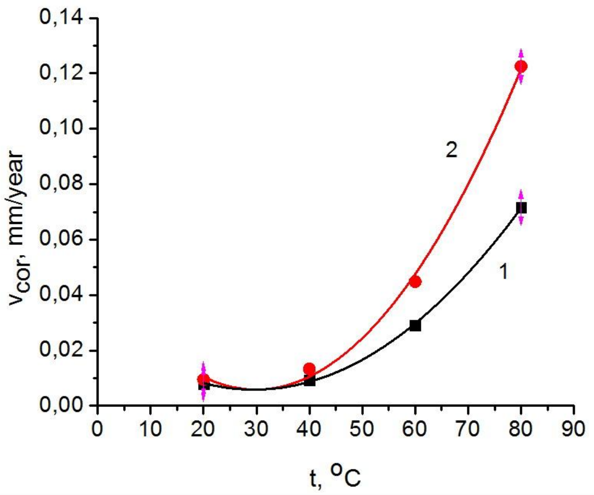

Figure 1. The dependence of the corrosion rate of carbon steel OL37 on temperature in water with 0.1 g / L disodium phosphate and 0.25 g / L sodium hexametaphosphate after 14 days of exposure according to water flow rate (L/min): 1 – 0,6; 2 – 2,4 L/min.

The analysis of the obtained data follows that under dynamic conditions, the inhibitor composition recommended as optimum in static conditions, is satisfactory only at a temperature lower than 50 °C. At 75°C the corrosion rate increases even more as velocity is higher. The effectiveness of the protective action of the tested binary mixture decreases accordingly.

Changing the composition of the binary mixture 0.25 g / L disodium phosphate 0.5 g / L of hexametaphosphate resulted in obtaining small values of corrosion at higher temperatures and the area effectiveness of protection over the entire range of temperature (figure 2 and table 2).

Table 2. The efficiency of the protective action, P(%) of two binary different mixtures (I and II) of disodium phosphate and sodium hexametaphosphate, after 14 days of exposure to corrosion of OL 37 steel in hot water, under dynamic conditions, depending on the temperature.

Binary mixture	Flow, L/min	P (%), at the temperatures:			
		20 °C	40 °C	60 °C	80 °C
I*	0,6	95,2	96,1	88,0	70,9
	2,4	94,4	96,1	84,2	59,6
II**	0,6	93,0	91,8	84,9	82,6
	2,4	91,5	89,0	78,5	73,4

** I - 0,1 g/L disodium phosphate + 0,25 g/L hexametaphosphate*

*** II - 0,25 g/L disodium phosphate + 0,5 g/L hexametaphosphate*

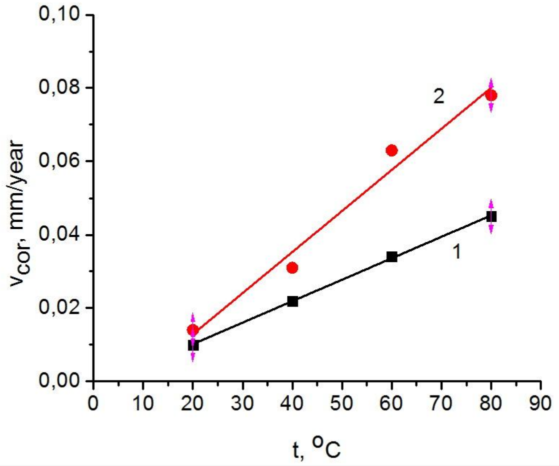

Figure 2. The dependence of the corrosion rate of OL 37 steel in hot water with 0.25 g/L disodium phosphate and 0.5 g/L sodium hexametaphosphate after 14 days of exposure, on temperature and on the water flow (L/min.): 1 - 0.6; 2 - 2.4.

Thus, if the corrosion rate for the first composition has increased approximately ten-fold to 75°C to a temperature of 20 °C, for the second composition increase was only four times. However the efficiency of protective action, about 80%, at temperature ≥60 °C remains unsatisfactory.

Figures 3 and 4 show the effect of added calcium nitrate to the water containing the binary inhibitor mixture of 0.25 g/L disodium phosphate + 0.5 g/L sodium hexametaphosphate on the rate of corrosion of OL 37 steel, at a temperature of 20 °C and, respectively, 75 °C. There is a relatively slow decrease of the corrosion rate at temperature of 20 °C to a drop at the temperature of 75 °C, for an addition of 0.4 g / L of calcium nitrate.

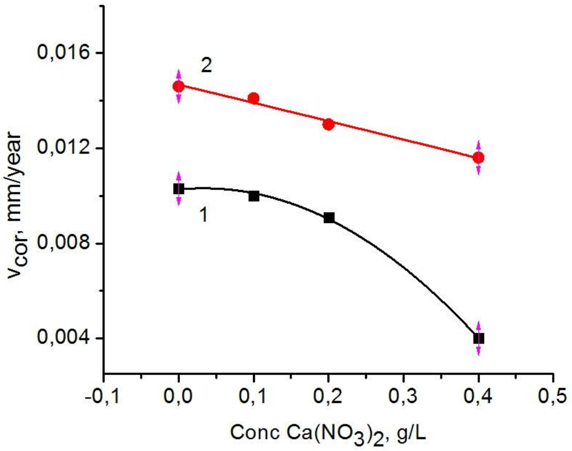

Figure 3. The influence of the addition of calcium nitrate on the corrosion rate of OL37 steel in water containing 0.25 g/L disodium phosphate + 0.5 g/L sodium hexametaphosphate, at 20 °C, after 14 days of exposure, depending on the water flow (L/min): 1 - 0.6 ; 2 - 2.4 .

The surface of carbon steel samples exposed at 75 °C in solution containing 0.4 g/L calcium nitrate showed a homogenous, glossy, which confirms the stable phosphate film formation. Figures 5 and 6 show the correlation between the rate of corrosion of OL 37 carbon steel, temperature, flow rate and the addition of calcium nitrate from water containing 0.25 g/L phosphate + 0.5 g/L hexametaphosphate. The addition of 2.5 g/L of calcium nitrate and a flow rate of 2.4 L/min.

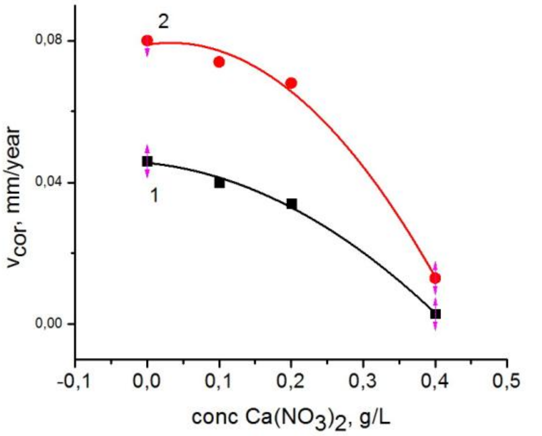

Figure 4. Influence of the addition of calcium nitrate on the corrosion rate of OL37 steel in hot water containing 0.25 g/L phosphate + 0.5 g/L Sodium hexametaphosphate at 75°C, at an exposure time of 14 days, depending on the water flow (L/min): 1 –– 0,6 ; 2 – 2,4 .

Increasing addition of calcium nitrate to 0.4g/L leads to the situation shown in figure 6 that the carbon steel corrosion rate decreases significantly at all temperatures, especially at 75°C, curves of corrosion rate with temperature going through a maximum at 50÷60°C. The carbon steel corrosion rate increases almost exponentially with the temperature of the water.

The presence of calcium ions enhances the protective effect of the binary mixture of phosphates, in particular at high temperatures as shown in Table 3.

This behavior is explained on the one hand by increasing the supply of oxygen to the metal surface, and, on the other hand, by the delay in forming the protective film at a higher speed water flow.

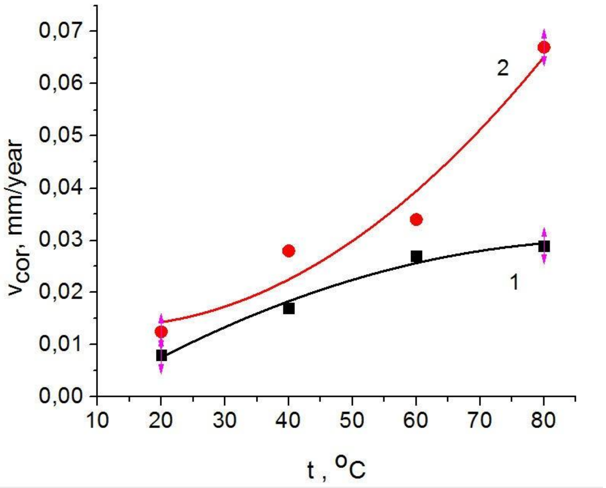

Figure 5. Variation of the OL37 steel corrosion rate on water temperature containing 0.25 g/L disodium phosphate + 0.5 g/L sodium hexametaphosphate + 0.25 g/L of calcium nitrate after 14 days of exposure, depending on the water flow (L/min): 1 - 0.6; 2 - 2.4

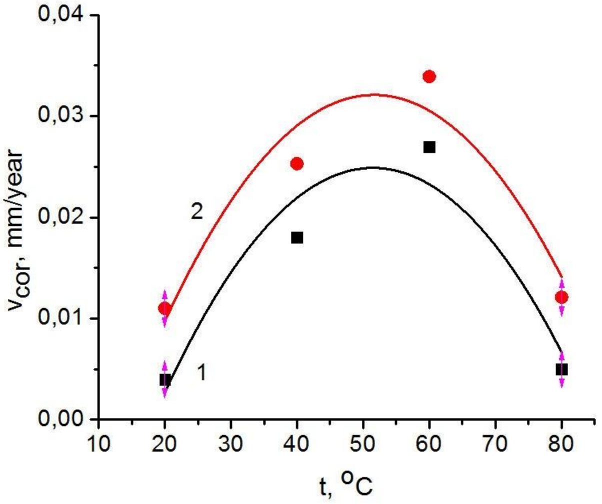

Figure 6. Variation of the OL 37 steel corrosion rate on water temperature containing 0.25 g/L disodium phosphate + 0.5 g/L sodium hexametaphosphate + 0.4 g / L of calcium nitrate after 14 days of exposure, depending on the water flow (L/min): 1 - 0.6; 2 - 2.4

Table 3. Influence of the calcium nitrate addition and temperature on the effeciency of the protective action, P, of the binary mixture 0.25 g/L disodium phosphate + 0.5 g/L sodium hexametaphosphate, after 14 days of exposure to corrosion-of OL 37 steel, in water under dynamic conditions.

$Ca(NO_3)_2$, g/L	Flow, L/min	P (%), at the temperatures:			
		20 °C	40 °C	60 °C	80 °C
0,25	0,6	93,4	92,0	87,4	87,5
	2,4	93,0	89,5	87,2	76,6
0,4	0,6	94,4	95,9	87,8	98,5
	2,4	91,2	90,7	88,2	96,5

4. CONCLUSIONS

The corrosion rate of OL carbon steel increases almost exponentially with the temperature of the water.

Increasing the flow of water in the system from 0.6 to 2.4 L/min rules to higher corrosion rates in all cases (curve 2 in Figure 1-6). This behavior is explained by one hand by increasing of the oxygen supply to the metal surface, and, on by the other hand, by the delay in forming the protective film at a higher speed water flow.

The addition of corrosion inhibitors determines the formation of a stable phosphate film with uniform appearance, shiny and resistant to hot water corrosion, which are the specific temperature conditions in heating water urban networks.

Higher flows could bring more oxygen to the metal surface and increase corrosion, but also determines the formation of a more protective film, demanding to determine the optimum inhibitor mixture composition and operating conditions.

5. REFERENCES

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