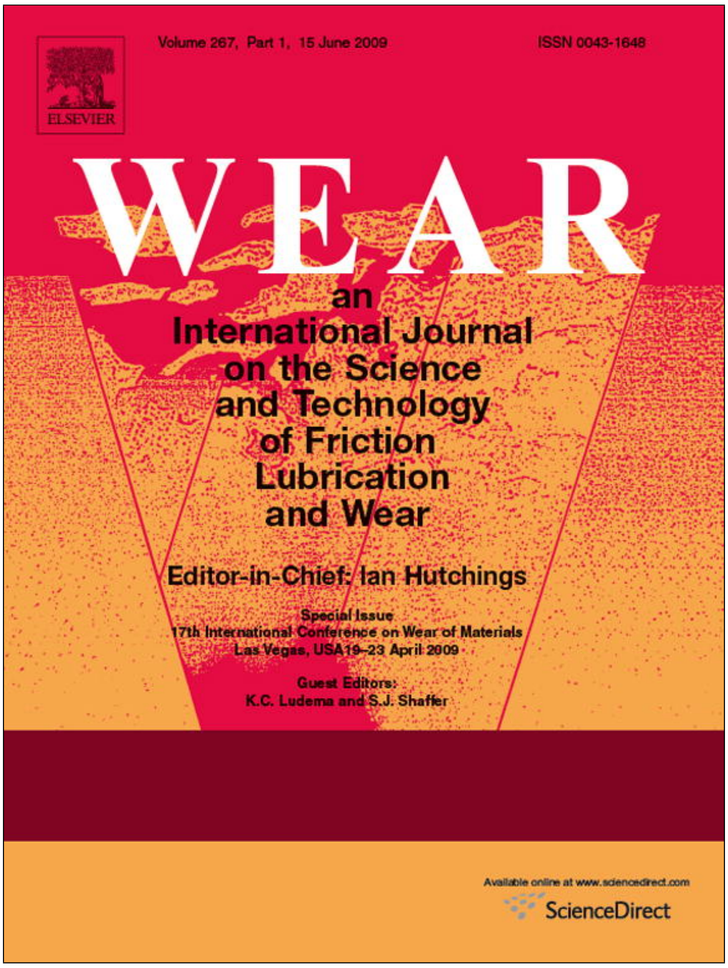
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Short communication

Amine type inhibitor effect on corrosion–erosion wear in oil gas pipes

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Oil transporting gas lines are exposed to corrosive–erosive wear mechanisms due to fluid flow conditions in gas transportation processes. Combined parameters like fluid flow regime and chemical composition of the wall deposited products increase oil gas pipes wearing. Corrosion–erosion laboratory tests on API X52 steel grade were performed to study corrosion rate effect of inhibitors added to residual water transported with gas in pipelines. Corrosion rate was measured by electrochemical methods when inhibitor concentration of 5, 50 and 100 ppm were utilized. Corrosion products are easily loosened due to lack of adherence and erosion is provoked by flow conditions with rapid pipe failure as a consequence. Fluid flow conditions were simulated in dynamic laboratory tests which were performed using a rotating cylinder electrode. Results were compared with horizontal oil pipe sections failed. Using amine type inhibitors reduced corrosion rate, but wear rate is increased in dynamic testing as it happens in gas pipes.

1. Introduction

The high demand of natural gas in all the world, has stimulated the development and optimization of a complex pipeline network necessary to carry natural gas from extraction fields to storage sites and from these to treatment plants and distribution facilities and, ultimately, to urban and industrial consumption areas. Nevertheless natural gas pipeline sections are being continuously replaced due to catastrophic damages produced by the natural gas stream resulting in high economical losses [1]. The adverse conditions in the walls of the steel pipes are due to the high concentration of corrosive agents carried in the gas stream, such as CO_2, H_2S, calcium and chlorine compounds which promote the deterioration of the steel pipe, mainly due to erosion–corrosion. In addition to the contaminants, the presence of condensed salt water usually encountered inside the pipeline aggravates the corrosion process. Process variables, such as flow rate, pressure and pipeline design interact to create a synergistic effect of corrosion and erosive wear of the pipe. Corrosion products are first deposited on the internal gas pipeline surface in the form of scales. These products, which are mainly $CaCO_3$ and $FeCO_3$, initially, act as a protective barrier to prevent the corrosion of the steel surface [2–4].

Several works have been performed related to the corrosion process of carbon steel, stainless steel and other metals in acid solutions [5–13]. In this work, the effect of the concentration of an amine type inhibitor on corrosion was evaluated on various samples of API X52 steel.

2. Experimental procedure

2.1. Materials

The samples used in the electrochemical test were obtained from an API X52 steel section pipe shown in Fig. 1. The samples were machined according to the geometry shown in Fig. 2a, Fig. 2b shows an example of one sample and Fig. 2c shows a complete assemblage of the metallic sample in the ceramic device used in the electrochemical test.

Table 1 shows the chemical composition results of the pipeline section made according ASTM E1085. Carbon and sulphur analysis were performed by combustion and infrared detection, respectively, according to ASTM E1019. Hardness measurements were taken on the transversal surface of the section pipe resulting on an average of 86 HRB. In addition Fig. 3 shows a metallographic micrograph of the metal base illustrating a typical ferritic and pearlitic microstructure of an API 5L X52 steel grade.

2.2. Electrochemical test

Electrochemical impedance spectroscopy (EIS) was undertaken in static and dynamic system. A picture for the EIS cell used in our experiment is shown in Fig. 4 where condensed water obtained from a real pipeline was used as electrolyte. Table 2 shows the

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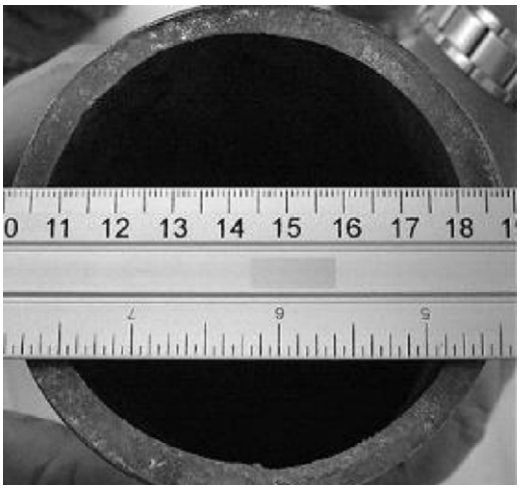

Fig. 1. Natural gas pipe section of 101.6 mm diameter of an API X52 steel grade.

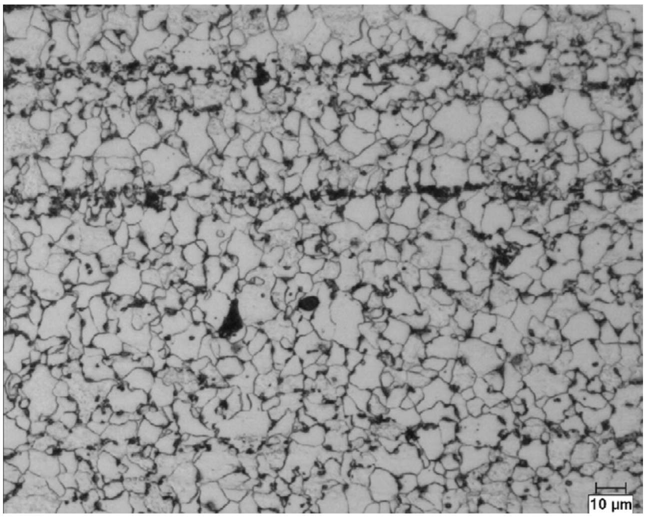

Fig. 3. Microstructure of the pipe section showing a typical microstructure of an API X52 steel grade containing pearlite bands phase in a ferrite matrix, 400×.

Table 1
Chemical composition (wt.%) gas pipeline steel.

Sample	API X52
C	0.070
Si	0.220
Mn	1.270
P	0.015
S	0.007
Cr	0.017
Mo	0.013
Ni	0.023
Al	0.036
Cu	0.053
Nb	0.055
Ti	0.002

Table 2
Physical chemistry analysis of the condensed salt water.

Parameter	Value
pH	7.45
$CaCO_3$	900 mg/l
Total hardness	850 mg/l
Phenolthalein alkalinity as $CaCO_3$	8 mg/l
Methyl alkalinity as $CaCO_3$	780 mg/l
Cl	9331 mg/l
Sulphate	94.76 mg/l
Total solids	18386.4 mg/l
Suspension solids	976.4 mg/l
Dissolved solids	17,410 mg/l
Electric conductivity	20,103 mMohos
CaO	340 mg/l
MgO	18.23 mg/l
CO_3	4.8 mg/l
HCO_3	469.2 mg/l

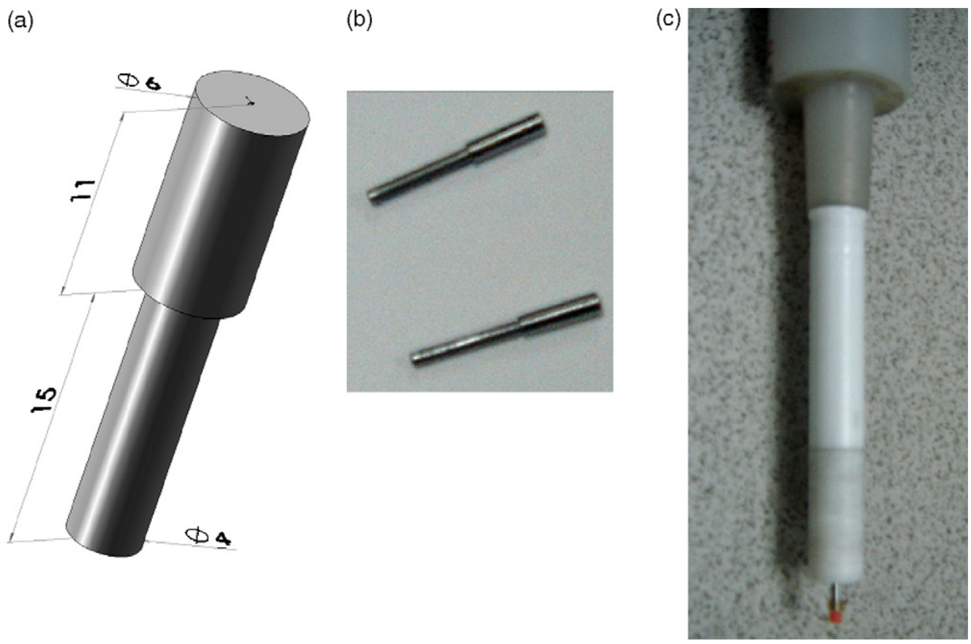

Fig. 2. (a) Schematic representation of the sample (mm) used in electrochemical test, (b) final sample machined and (c) mounted sample with an exposed area of 18 mm^2.

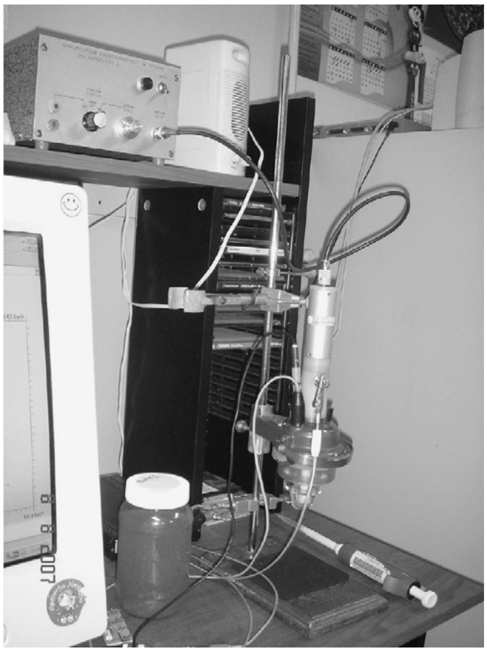

Fig. 4. EIS cell experiment with a rotational speed of 1500 rpm.

physical chemistry analysis of the condensed salt water; it can be noted high level presence of corrosion agents like chlorides, sulphides, carbonates and bicarbonates. The electrochemical dynamic test was carried out at room temperature with a tangential speed of 157.08 m/s for 30 min with various amine concentrations: 0, 5, 50 and 100 ppm. The filmic amine type inhibitor has antibacterial agents in order to inhibit the formation of microorganisms. Fig. 5 shows a spectrogram of the amine type inhibitor obtained by infrared spectroscopy analysis using a FTIR NICOLET 500 spectrometer; it can be confirmed the presence on the amine functional groups (R–NH–R).

3. Results and discussion

Fig. 6a and b shows the Nyquist diagrams (EIS) corresponding to the static and dynamic electrochemical test, respectively. According to these diagrams, the different levels of corrosion can be noted between them due to different loop diameters in every system. The real and imaginary impedance values obtained for static system reveal that the corrosion process is accelerated at the highest content of amine (100 ppm), this initial observation was in agreement to the literature [14,15] except for the middle amine content (50 ppm) which retarded the corrosion process. For dynamic system, the behavior was similar to static system with the exception that the first was more aggressive because of a hydrodynamic fac-

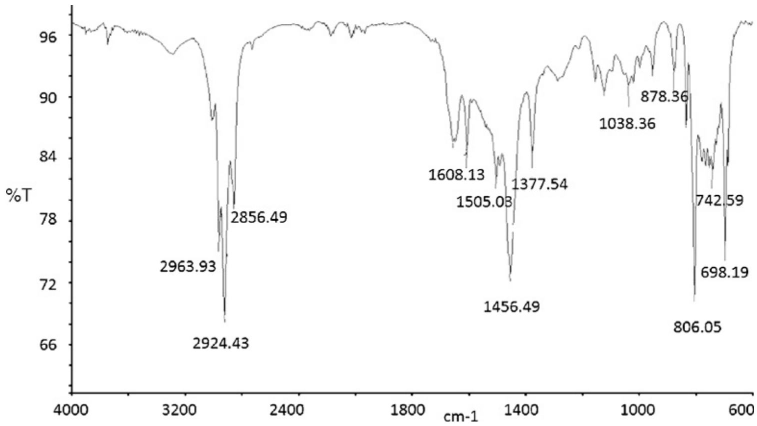

Fig. 5. Infrared spectroscopy spectrogram of the amine type inhibitor.

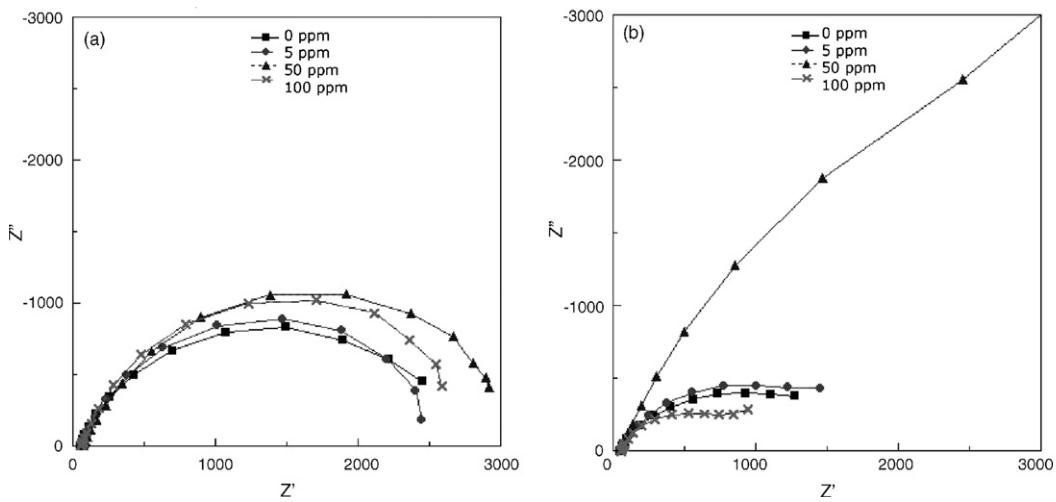

Fig. 6. Nyquist diagrams with amine type inhibitor concentration of 0, 5, 50 and 100 ppm corresponding to electrochemical test in (a) static system and (b) dynamic system (1500 rpm).

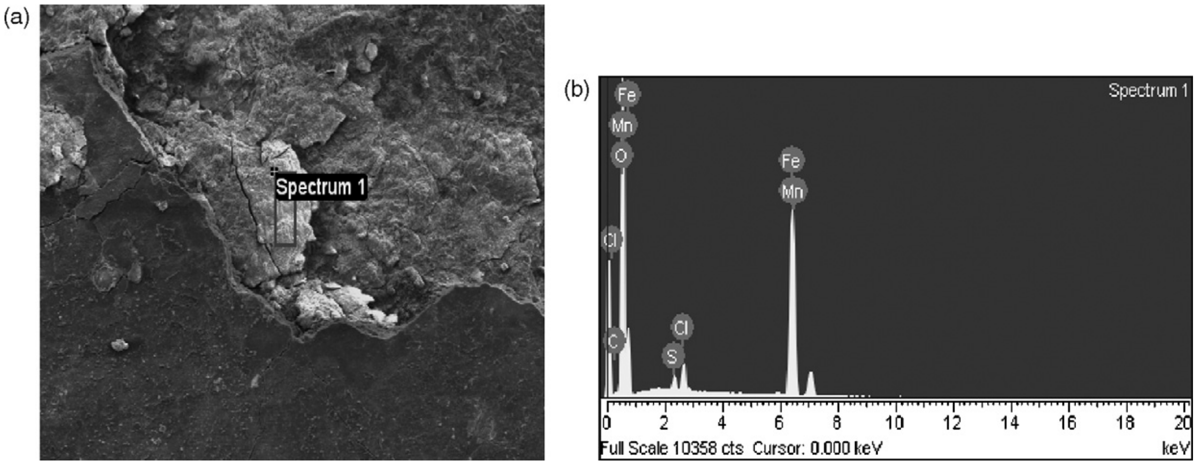

Fig. 7. (a) SEM micrograph corresponding to sample tested in dynamic extended system test, 100 ppm amine concentration and (b) EDS analysis showing presence of Cl and S.

tor. The condition of 50 ppm amine content level, presented the best corrosion resistance. This could indicate a good scenario in a real environment due to the formation of a stable and resistant passive film adhered on the surface. In a visual inspection of the sample surfaces after electrochemical dynamic test it was possible to observe a thin dark layer with poor adherence. Fig. 7a shows a SEM micrograph taken on the surface of the sample corresponding to hydrodynamic system with 100 ppm amine concentration. A dark fragile film can be noted on the surface after an extended test. Fig. 7b shows a spectrum by EDS indicating the presence of S and Cl in this film. The results suggest that the adherent film on the steel surface along with hydrodynamic factors like turbulent gas stream has a direct influence corrosion rate. High level concentration of amine inhibitor leads instability of the film resulting in electrochemical activation between corrosive agents of the condensed salt water and the steel surface; as a consequence different fragile scales (Fe_xS_x, $CaCO_3$ and $FeCO_3$) are easily loosened and detached in certain sites due to the turbulent stream; it exposes fresh steel surface areas to the highly corrosive environment (Cl ions) resulting in a severe pitting corrosion attack.

4. Conclusions

- The corrosive wear of an API X52 steel immersed in condensed salt water with amine as inhibitor was evaluated using the EIS technique for static and dynamic conditions.
- Based on the EIS evaluations, 50 ppm amine concentration presented the best corrosion resistance for the static and dynamic systems. This amine concentration produces a stable organic film reducing the scale formation and its susceptibility erosion.
- High dosage (100 ppm) of amine inhibitor resulted in a less stable film leading to scaling and initiation of pitting corrosion.

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