MICROBIOLOGICALLY INFLUENCED CORROSION OF CARBON STEEL IN THE PRESENCE OF SULPHATE REDUCING BACTERIA

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ABSTRACT

Sulphate-reducing bacteria (SRB) are the most important organisms in microbiologically induced corrosion.
In this context, the paper presents an assessment (by experimental tests) of the behaviour of carbon steel samples (SA106gr.B) in SRB media.
Some of samples were immersed in microbial environment in order microbiological analysis of their surface and another part was used to perform accelerated electrochemical tests to determine electrochemical parameters for the system carbon steel / microbial medium (corrosion rate, the polarization resistance of the surface, susceptibility to pitting corrosion).
The surfaces of the tested samples were analyzed using the optical and electronic microscope, and emphasized the role of bacteria in the development of biofilms under which appeared characteristics of corrosion attack.
The correlation of all results confirmed that SRB accelerated the localized corrosion of the surfaces of SA 106gr.B carbon steel.

Key words: microbiologically induced corrosion, carbon steel, corrosion rate, sulphate reducing bacteria

Introduction

Sulfate-reducing bacteria (SRB) are the most important organisms in microbiologically induced corrosion. Sulphate-reducing bacteria are a group of diverse anaerobes which carry out reduction of sulfur compounds such as sulfate, sulfite, thiosulfate and even sulfur itself to sulfide. Although SRB are often considered to be strictly anaerobic, some genera tolerate oxygen.
In aquatic environments, microorganisms attach to surfaces and interact in complex ways to form biofilms and produce an environment at the biofilm / metal interface that is radically different from that of the bulk medium in terms of pH, dissolved oxygen, organic and inorganic species.
When the rate of oxygen diffusion into biofilm is less than the rate of respiration, areas within the biofilm become anaerobic and anaerobic bacteria flourish even if the bulk medium is saturated in oxygen[1].

Experimental

The materials

The metallic coupons used in the tests cutted as plates of about 30mm in length, 15mm wide and 1.5mm thick, were made of carbon steel SA 106 gr.B. The samples were polished using a wet emery paper and degreased in acetone.

The chemical composition (% wt) of SA 106 gr.B is: C-0.30; Mn-0.29-1.06; P- max.0.048; S- max 0.058; Si- min 0.10

Media

The samples were exposed 60 days in inoculated medium with SRB-9.5x10^9 bacterial cells/ml liquid.

The apparatus

- The electrochemical measurements were performed using the EG&G Princeton Applied Research Model 273 potentiostat/galvanostat. The electrodes used in the electrochemical cell (which contained the tested medium) were: the working electrode-the sample, two auxiliary graphite electrodes symmetrically placed vs. the working electrode and the reference electrode (SCE);
- The metallographic examinations were made using a Neophot microscope;
- The SEM investigation has been assessed using TESCAN VEGA II LMU system.

Results and discussion

- Potentiodynamic sweep technique [2]

The main parameters of PD measurements were:

- the potential range: -250mV ÷+500mV
- the potential sweep rate: 0.5 mV/sec
- the temperature of the testing solutions: the room temperature.

Fig. 1 shows the potentiodynamic curves in SRB media, both at the initial moment and after 60 days of immersion. Based on the data from Tafel slopes and polarization resistance, the values of the potentiodynamic parameters were determined (Table 1).

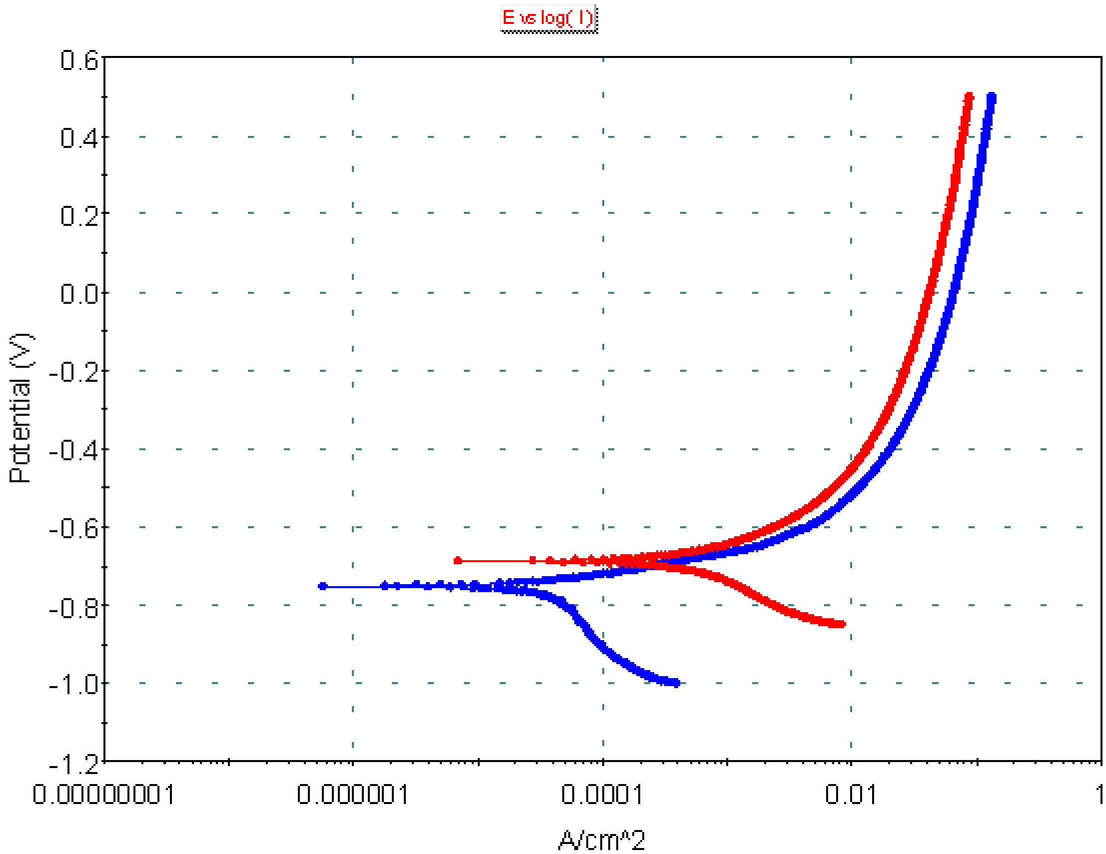

Fig.1. *The PD curves of SA106gr.B in SRB media:*
initial
after 60 days of immersion

Table1. *The main electrochemical parameters obtained by potentiodynamic sweep techniques in SRB media:*

t=0 (initial)	**t=60 days of immersion**
E(I=0) (mV): -751.195 Icorr (μA): 35,58 v_{cor} (mm/year): 0.11 Rp (Ω·cm^2) : 2500	E(I=0) (mV): -689.456 Icorr (μA): 502,6 v_{cor} (mm/year): 1.68 Rp (Ω·cm^2) : 80

The growth of a biofilm on the surface of the samples is evidenced by the decrease of polarization resistance after 60 days of immersion- from 2500 Ω·cm^2 to 80 Ω·cm^2 and by increase of the corrosion rates of the surfaces- from 0.11 mm/year to 1.68 mm/year.

The lower polarization resistance in the presence of SRBs indicates the lost of protected surface layer (passive layer).

- Metallographic analysis

Fig.2 shows the microscopic aspect of the surfaces after 60 days immersion in SRB.
After 60 days of immersion in SRB, on the surface of the exposed samples some deposits were developed. The biofilm and induced products are inhomogeneous in distribution as well as thickness, as shown in Fig.2. After removing of the biofilm from the metallic surface and a light polishing, some pits were observed (Fig.3).
The pits were partial filled with a black composition of FeS and also with an active biological material, under which the corrosion was continued.

Fig.2. *The aspect of the exposed sample in SRB medium*

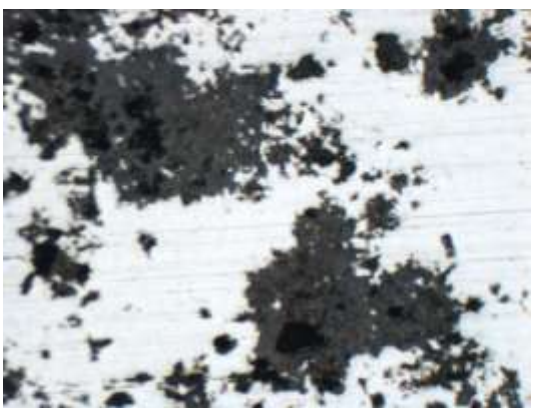

Fig.3. *The microscopic aspect of the exposed surface in sulphate-reducing bacteria*

Scanning electron microscopy (SEM) provided information about the morphology of microbial cells and colonies, their distribution on the surface, the presence of extracellular polymeric substances (EPS) and the nature of corrosion products (Fig.4).

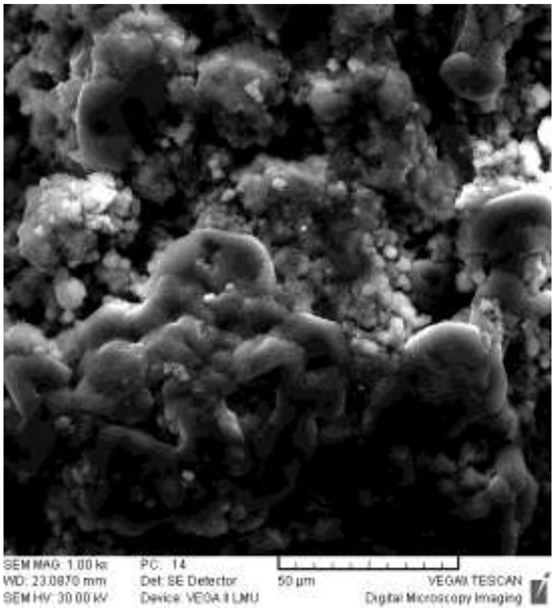

Fig.4. *Biofilm formed by sulfate-reducing bacteria on the surface of SA106gr.B, visualized using SEM*

Composition analysis by energy dispersive spectroscopy (EDS) revealed that the deposits are compose of Fe, O, Mn and S (Fig.5). The peaks of Fe, O and S indicate the presence of iron-sulfur or iron oxide compounds, which are due to SRB growth on the carbon steel samples. The appearance of S peak is due to the presence of metals sulphide formed as a result of SRB metabolic activities. The ferrous sulphide layer was formed on metal surface by the reaction of Fe with hydrogen sulphide produced by SRB.

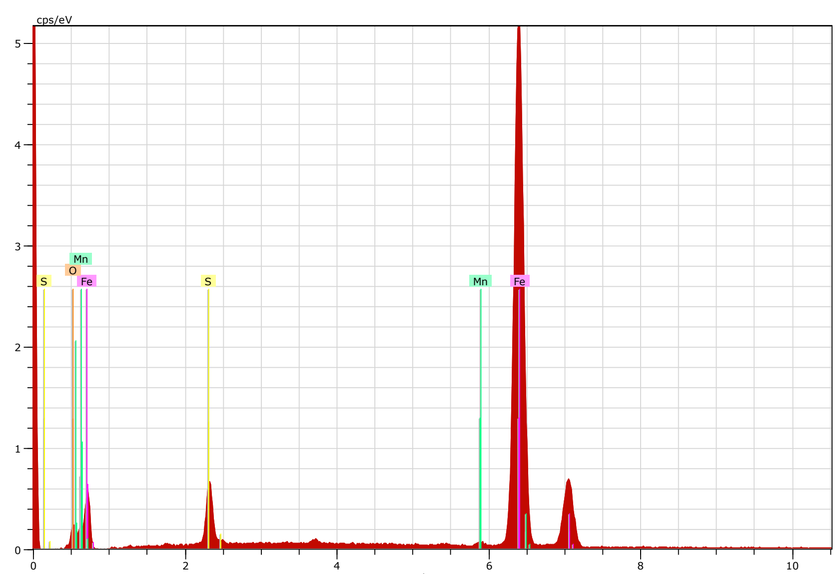

Fig.5. ***EDS*** *spectrum of deposits on the surface of SA106gr.B in SRB media*

Conclusions

The behaviour of carbon steel samples (SA106gr.B) in SRB media was studied. The following points can be emphasized:

- Influenced by the metabolic activity of SRB the corrosion rate of SA106gr.B was increased after 60 days immersion in microbial media;
- Pitting corrosion was also induced in the presence of SRB.

References

[1] Videla H.A., Herrera L.K., 2005 – Microbiologically influenced corrosion: looking to the future, Int. Microbiol., Sept., 8 (3), 169-180.

[2] G.Schmitt – Sophisticated electrochemical metods for MIC investigation and monitoring, Materials and Corrosion 48,586-601 (1997)