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Corrosion Protection of Carbon Steel Using Natural Seaweeds from Seawater †

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Abstract: The aim of this work was to investigate the corrosion inhibition effect of natural seaweeds in seawater on carbon steel. The corrosion efficiency of carbon steel in the absence and the presence of natural seaweeds in seawater was evaluated by the gravimetric method at room temperature and calculating the corrosion rate and protection degree. The experimental results showed that the corrosion rate on carbon steel decreased when the seaweeds were used. In addition, the value of protection degree (P) was greater than 60% when seaweeds were used. Natural seaweeds reduce the corrosion rate and can be considered an ecofriendly corrosion inhibitor for carbon steel.

Keywords: seaweed; carbon steel; seawater

1. Introduction

Corrosion of different metals such as carbon steel, iron, boron steel, aluminum is caused by the chemical interaction with their corrosion medium [1–5].

Today, the various extracts of petals, leaves, peels, seeds, or roots have been used as ecofriendly and effective corrosion inhibitors in different corrosion media [1–4]. Seaweeds are plants (marine macroalgae) that grow abundantly in the shallow waters of sea, estuaries, and backwaters [5]. The natural extracts have many advantages such as having excellent anticorrosive activity, nontoxicity and biodegradability, and can be extracted by simple methods at low cost [1–5].

The research in the field of "green" corrosion inhibitors shows that the inhibitors, when added in a small concentration into a corrosion medium, reduce the corrosion rate of the exposed metal to that medium. Inhibitors can also alter the corrosive medium into a noncorrosive or less corrosive medium through their interaction with the other species. This occurs depends on the composition of the inhibitors or their corrosive medium. Due to the interaction of inhibitors with the metal surface, a passive film is form that protect the metal from corrosion attack [1–6]. In addition, the green corrosion inhibitors are nontoxic, biodegradable, ecofriendly, and do not contain heavy metals or other toxic compounds [4–9].

Deyab [5] studied the inhibition effect of seaweed extract on the corrosion of mild carbon steel in saline formation water. The data exhibit that the inhibition efficiency increases with increasing extract concentration, while the corrosion rate decreases with extract concentration. It was found that

the seaweed extract can reduce the corrosion rate of mild carbon steel in saline formation water by approximately 93% [5].

2. Materials and Methods

Samples of natural seaweeds and seawater used for the corrosion tests were taken from the Tsarevo area, southern Bulgaria, and used without any purification or filtration. Small plates of carbon steel (10 × 15 mm) were used for corrosion tests, polished using silicon carbide grinding paper with grit P400, degreased with sodium carbonate, rinsed in distilled water, and dried with ethanol. After that, the samples were weighed accurately using an analytical balance (Kern KB, KERN & SOHN GmbH, Balingen, Germany). They were then suspended entirely in glass vessels that contained 25 mL of seawater, without and with natural seaweeds (10 g) (Figure 1). The corrosion experiments were examined by the gravimetric method for 7 days at room temperature (22 ± 2 °C) using one sample for each test. After the corrosion time ended, samples were taken out, washed with distilled water, dried at room temperature, and weighed accurately.

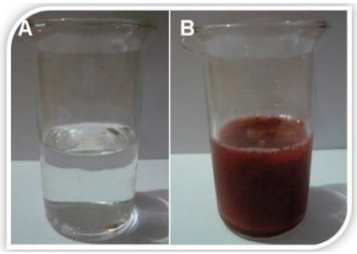

Figure 1. The glass vessels that contain seawater, without (**A**) and with natural seaweeds (**B**).

The surface morphology of the carbon steel, before and after corrosion tests, was examined using a digital optical microscope (MT4096, USB, Media-Tech, Bratislava, Slovakia, magnification 300×).

3. Results

To evaluate the corrosion efficiency of carbon steel in the absence and the presence of natural seaweeds in seawater, corrosion rate and protection degree were calculated.

Corrosion rate (CR, g/m^2 h) for the samples was calculated by Equation (1) [7,8]:

$$CR = \frac{w_i - w_f}{A \cdot t} \times 100, \quad (1)$$

where: CR—corrosion rate (g/m^2 h); w_i—initial weight of carbon steel coupon (g); w_f—final weight of carbon steel coupon (g); A—area of the coupon of carbon steel (m^2); and t—corrosion time (h).

The protection degree (P) was calculated using Equation (2) [7,8]:

$$P = \frac{CR_i - CR_f}{CR_i} \times 100, \quad (2)$$

where: CR_i—corrosion rate in the absence of seaweeds and CR_f—corrosion rate in the presence of seaweeds (g/m^2 h).

The values of corrosion rate (CR) and protection degree (P) obtained by weight loss data are presented in Table 1.

Table 1. The values of CR and P for samples of carbon steel in the different corrosion media.

Corrosion Medium	CR (g/m^2 h)	P (%)
seawater	0.2012	-
seawater without natural seaweed	0.1194	40.66
seawater with natural seaweed	0.0672	66.60

The surface morphology of carbon steel samples was examined in the absence and the presence of natural seaweeds in seawater (Figure 2).

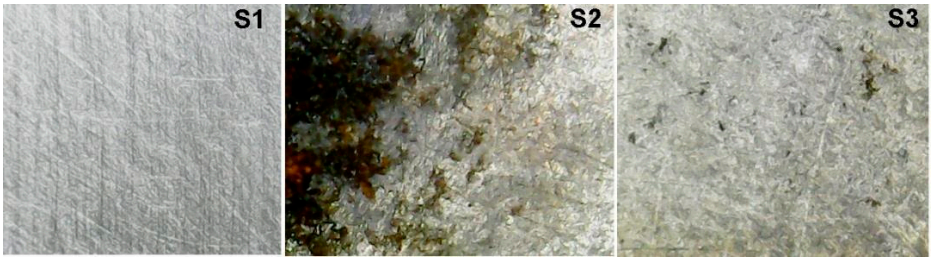

Figure 2. Surface morphology images of the carbon steel: blank (**S1**); immersed in seawater without natural seaweeds (**S2**); immersed in seawater with natural seaweeds (**S3**).

4. Discussion

The results presented in Table 1 indicate that the best value of P (66.60%) was obtained in the corrosion medium of seawater with natural seaweeds.

The surface morphology images show that the corrosion reaction does not take place homogeneously over the surface of carbon steel in the absence of natural seaweeds in seawater (Figure 2). In comparison with the surface exposed in the presence of natural seaweeds in seawater, the surface of carbon steel was damaged by the lack of natural seaweeds. It can be seen that seaweeds protected the surface of carbon steel remarkably well in comparison to the solution without seaweeds [7,9].

5. Conclusions

The results show that the corrosion rate calculated by the gravimetric method of carbon steel in seawater decreased when natural seaweeds were used.

The value of protection degree (P) was greater than 60%, after 7 days, when natural seaweeds were used in the seawater. Also, the natural seaweeds reduce the corrosion rate and can be considered as a suitable inhibitor for carbon steel in seawater.

The morphological image of the surface carbon steel plate shows that the seaweeds protect the carbon steel surface.

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Conflicts of Interest: The authors declare no conflict of interest.

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