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Corrosion Inhibition of a Green Scale Inhibitor Polyepoxysuccinic Acid

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Abstract: The corrosion inhibition of a green scale inhibitor, polyepoxysuccinic acid (PESA) was studied based on dynamic tests. It is found that when PESA is used alone, it had good corrosion inhibition. So, PESA should be included in the category of corrosion inhibitors. It is not only a kind of green scale inhibitor, but also a green corrosion inhibitor. The synergistic effect between PESA and Zn^{2+} or sodium gluconate is poor. However, the synergistic effect among PESA, Zn^{2+} and sodium gluconate is excellent, and the corrosion inhibition efficiency for carbon steel is higher than 99%. Further study of corrosion inhibition mechanism reveals that corrosion inhibition of PESA is not affected by carboxyl group, but by the oxygen atom inserted. The existence of oxygen atom in PESA molecular structure makes it easy to form stable chelate with pentacyclic structure.

Keywords: Green scale inhibitor, polyepoxysuccinic acid, corrosion inhibition, synergistic effect.

PESA, which is free of nitrogen and phosphorus, is one of the two green water treatment agents recognized all over the world[1]. The development of PESA breakthroughs the traditional way in which different monomer groups connect together simply. An oxygen atom is inserted into PESA molecular chain. This makes it superior to polyacrylic series in scale inhibition[2]. The research has mainly concentrated on scale inhibition but lacked on the corrosion inhibition and corrosion inhibition synergistic effect till now. PESA is used as scale inhibitor and phosphor series compounds as corrosion inhibitors for all the existing developed formulas. Although these formulas have good performance, they lose the green advantage of PESA. The present paper breakthroughs the traditional idea from which PESA is used with phosphor and azoles. Our study is on corrosion inhibition synergistic effect between PESA and the compounds free of nitrogen and phosphorus. The best corrosion inhibition formula is obtained and the corrosion inhibition mechanism is also discussed from the view of molecular structure.

The experiments were carried out by using standard rotating weight loss tests on a dynamic corrosion test instrument. Standard carbon steel specimens were fixed on a rack and put into the bottle filled with standard corrosion water ($CaCl_2 \cdot 2H_2O$ 735 mg/L, $MgSO_4$ 493 mg/L, NaCl 658 mg/L, $NaHCO_3$ 168 mg/L) plus inhibitor. The bottle was mounted in a constant temperature bath at 50 °C The specimens were rotated at 90 rps.

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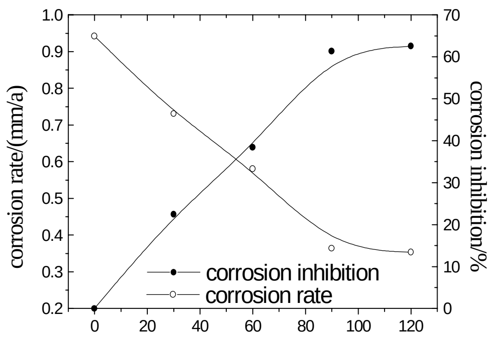
The water was supplied every 4 hours because of evaporation. After 72 hours, experiment was stopped. Corrosion rate and percentage inhibition efficiency were calculated with the equations as follows:

$$X=87600\,(W-W_0)\,/\,(ADT)$$

$$X_2\,(\%)=100\,(X_0-X_1)\,/\,X_0$$

Here, X is corrosion rate, mm/a; W is specimen weight before test, g; W_0 is weight after test, g; A is specimen surface area, cm^2; D is its density, g/cm^3; T is test time, h; X_2 is inhibition efficiency, %; X_0 is uninhibited corrosion rate, mm/a; X_1 is inhibited corrosion rate, mm/a.

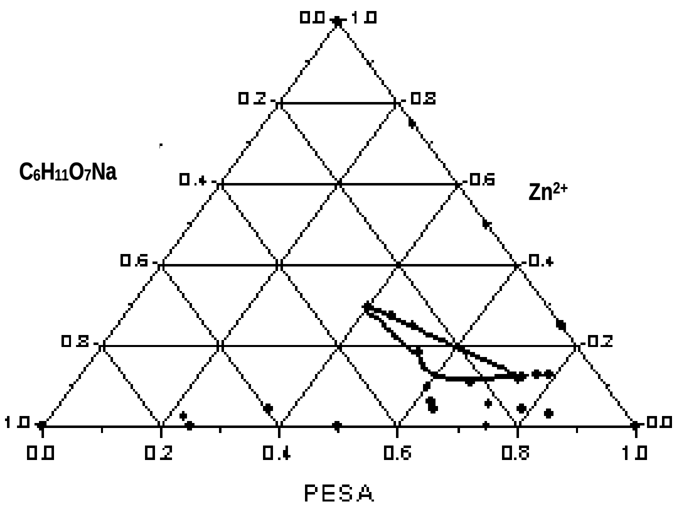
Figure 1 The corrosion inhibition of PESA for carbon steel



The results are shown in **Figture 1**. In all the references about PESA, PESA is researched as a kind of highly effective scale inhibitor or chelate. The corrosion inhibition of PESA has never been studied until now. To obtain good corrosion inhibition effect, the existing formulas are applied with the aid of other corrosion inhibitors such as phosphor series[2,3]. However, It is evident from our experimental data (**Figure 1**) that when PESA dosage is low, PESA has a certain corrosion inhibition effect on carbon steel. With the increase of PESA dosage, corrosion inhibition increases. When dosage is more than 90 mg/L, corrosion inhibition efficiency is over 60 %. These data show that corrosion inhibition of PESA is better than the typical corrosion inhibitors, sodium benzoate and sodium salicylate[4]. For this reason, PESA should be included in the category of corrosion inhibitor. It is not only a kind of green scale inhibitor, but also a green corrosion inhibitor.

The synergistic effect among PESA (green compound[4]), Zn^{2+}(safe but low effective corrosion inhibitor[4]) and sodium gluconate was studied. The result is shown in **Figure** 2. It is found that when PESA and Zn^{2+} are used together, the inhibition efficiency is worse than that of each alone. Namely, there is no synergistic effect between PESA and Zn^{2+}. PESA with sodium gluconate shows no synergistic effect either. However, when PESA, Zn^{2+} and sodium gluconate are simultaneously used and the content ratio is inside the loop area of the bold line area in **Figure 2**, the formulas give corrosion inhibition efficiency more than 96％～99％ at 50 mg/L of total dosage. However, when their dosage ratio is on the right side and under the bold line area in **Figure 2**, although PESA content is high, corrosion inhibition efficiency is still poor. Because the best region of corrosion inhibition efficiency is close tightly to the worse one, it is implied that there exists a value effect for the contents of PESA, Zn^{2+} and sodium gluconate in this formula.

Figrue 2 The synergistic effect of PESA, Zn^{2+} and sodium gluconate for carbon steel



To understand the corrosion inhibition mechanism of PESA, the synergistic effects of polyacrylic (PAA) and acrylic acid-maleic acid copolymer (PAA-HPMA), the molecular structures of which are alike, were also studied under the same condition. Experimental data show that PESA has one more carboxyl group of PAA, its corrosion inhibition efficiency (99.09％) is better than that of PAA (27.81％); PAA/HPMA has one more carboxyl group than PESA, but its corrosion inhibition efficiency is only 6.27%. It is inferred that the corrosion inhibition of PESA is not mainly affected by carboxyl group, but by the oxygen atom inserted. The existence of oxygen atom in PESA molecular structure makes it easy to form stable chelate with pentacyclic structure.

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