

Study on the Corrosion Inhibition of Benzotriazole in the Blast Furnace Gas Condensate Water

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Abstract. Preparation of the corrosion inhibitor was carried out by adding the benzotriazole in sodium hydroxide solution in view of the corrosion problem of blast furnace gas condensate in iron and steel enterprises. Real-time corrosion rate of blast furnace gas condensate water with and without the corrosion inhibitor was monitored through corrosion rate tester. The average real time corrosion rates of the blast furnace gas condensed water contacting the various dosage of the corrosion inhibitor were lower than the average real time corrosion rates without adding the corrosion inhibitor. Corrosion inhibition behavior of the corrosion inhibitor on carbon steel in the blast furnace gas condensed water using weight loss measurement method.

1. Introduction

With the continuous development of China's iron and steel enterprises, efforts to reduce the cost of blast furnace smelting and enhance the intensity of blast furnace smelting have become one of the goals pursued by various iron and steel enterprises. As a widely used technology to enhance the blast furnace smelting intensity and reduce the cost of blast furnace smelting, such as oxygen-enriched pulverized coal injection technology and sinter spraying CaCl_2 solution technology, which all can lead to the content of acid gases (such as SO_2 , SO_3 , H_2S , HCl , etc.) in blast furnace gas higher[1-3]. Especially after the dry gas dedusting technology is widely used in iron and steel enterprises, almost all of the above acid gases are retained in the gas and cannot be discharged. As a result, the pH value of the condensate water of blast furnace gas decreases obviously, and the acid corrosion of blast furnace gas gradually appears, which has become the main factor affecting the safe operation of blast furnace gas pipelines and their auxiliary equipment [4]. Therefore, how to effectively prevent and control the acid corrosion of blast furnace gas is an important issue facing iron and steel enterprises.

Wang Xueming et al. [5] determined the idea of adjusting pH by spraying pesticide through hanging piece simulation experiment in view of the rapid corrosion of blast furnace gas pipeline network of Shouqin Company in 2011. Ammonia was determined as the preferred chemical through comparative test and analysis of NaOH , Na_2CO_3 and ammonia, which dosage was 10000 mg/L. Ammonia could be used as a reagent to adapt to the great change of condensate pH in the pipeline network. When the reagent is excessive, it will not have a negative impact on the pipeline, and has a protective effect on the pipeline. The ammonia spraying method needs less dosage, and all the condensate water is used for steel-making slagging treatment, which will not cause environmental pollution.

Chen Chao et al. [6] summarized and discussed the preventive measures for corrosion of gas pipelines, such as spraying NaOH solution on the rear pipeline of TRT in Shougang Group Company



to control acid corrosion of gas condensed water. Its advantage is that it could better control the acidity of blast furnace gas. But it has many disadvantages, such as taking up much room, severe corrosion when alkali is prepared and transported, the larger maintenance workload, and so on. The addition of CaCl_2 reinforcer in sinter was controlled to control the acidity of blast furnace gas in Jigang Company. Its advantage is that there is no investment in equipment and facilities, but its disadvantage is that the fluctuation of CaCl_2 additives will affect the strength control of sinter feeding, which may affect the blast furnace operation states and is not conducive to the stable operation of production. The alkali adding device is adopted in the spray equipment of dry gas dedusting blast furnace gas in the steel plant of Shougang and Henggang, which turns the original neutral water mist into the alkaline water mist. The purpose is to neutralize the sour gas in the gas, and reduce the acidity of the condensed water in the pipeline. That is to alleviate the corrosion phenomenon of the gas pipeline.

We prepared the corrosion inhibitor by adding the benzotriazole in sodium hydroxide solution to effectively alleviate the corrosion problem of blast furnace gas in view of the corrosion problem of blast furnace gas condensate in iron and steel enterprises. If the corrosion inhibitor was adopted in the blast furnace gas, which will prolong the service life of gas pipelines and guarantee the safe and stable operation of blast furnace gas system. That will promote the development of iron and steel enterprises in China, and have significant economic and social benefits.

2. Experimental

2.1. Preparation of the Corrosion Inhibitor

Preparation of the corrosion inhibitor was carried out by adding the benzotriazole in sodium hydroxide solution (mass content was 20%). Then stir with a magnetic stirrer until benzotriazole dissolved completely. And then dilute the corrosion inhibitor with deionized water to about 10 mg/mL. Keep the prepared corrosion inhibitor in the refrigerator.

2.2. Real-time Corrosion Rate Monitoring

A QYFS-I type corrosion rate tester equipped with two measuring electrodes and the associated testing software was used to monitor the real-time corrosion of A3 carbon steel in the blast furnace gas condensed water. The following testing steps were adopted for studying the corrosion inhibition performance: the corrosion inhibitor was added to a beaker containing 200mL of the blast furnace gas condensed water. The two electrodes used for corrosion measurements were rinsed with absolute alcohol and dried, before their installations into the test system. After the corrosion detector was placed into the beaker containing the blast furnace gas condensed water with or without corrosion inhibitor, corrosion monitoring commenced. The average corrosion rate was recorded at 11 min intervals for a total testing period of 72 h. Composition and properties of the blast furnace gas condensed water are given in table 1.

Table 1. Composition and Properties of the Blast Furnace Gas Condensed Water

pH	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	OH^- (mg/L)	Conductivity ($\mu\text{s/cm}$)
5.68	72.3	5.0	5.0	608.1	1710

2.3. Weight Loss Measurement of the Rotating Hanging Coupons Test

Corrosion inhibition behavior of the corrosion inhibitor on carbon steel in the blast furnace gas condensed water using weight loss measurement were assessed in accordance with Chinese Standard GB/T 18175-2000. A XYZK-A type rotating hanging coupon test device was used for measuring weight loss. The following procedures were adopted: The corrosion inhibitor was added in the 1800 mL of the blast furnace gas condensed water. Then the beaker containing experimental water was

placed into the water bath of the rotating hanging coupon test device and the experimental temperature set to $45 \pm 1^\circ\text{C}$. Carbon steel samples ($50\text{mm} \times 25\text{mm} \times 2\text{mm}$) were then suspended in the blast furnace gas condensed water with and without corrosion inhibitor. The rotating speed of the rotating axis was 75 rpm. The experimental period lasted 72 h. The corrosion rate of the steel sample was calculated with equation (1).

$$X = \frac{8760 \times 10 \times (W_0 - W)}{A \times D \times T} = \frac{87600 \times (W_0 - W)}{28 \times 7.85 \times 72} \quad (1)$$

Where X is the average corrosion rate of carbon steel in blast furnace gas condensed water (mm/y); the 8760 and 10 are conversion factors for number of hours in a year and dimensional (cm to mm) conversion respectively; W_0 and W are the weights (g) of the test samples prior to and after testing; A is the steel sample surface area (28 cm^2); D is the density of the steel samples (7.85 g/cm^3); T is test time (72 h).

Corrosion inhibition efficiency of the corrosion inhibitor was calculated from equation (2).

$$\eta = \frac{(X_0 - X_1)}{X_0} \times 100\% \quad (2)$$

Where η is the corrosion inhibition efficiency of the corrosion inhibitor (%); X_0 is the annual corrosion rate of carbon steel in the absence of blast furnace gas condensed water (mm/y); X_1 is the annual corrosion rate of carbon steel in the presence of the blast furnace gas condensed water (mm/y).

3. Results and Discussion

3.1. Real-time Monitoring of Corrosion Rate

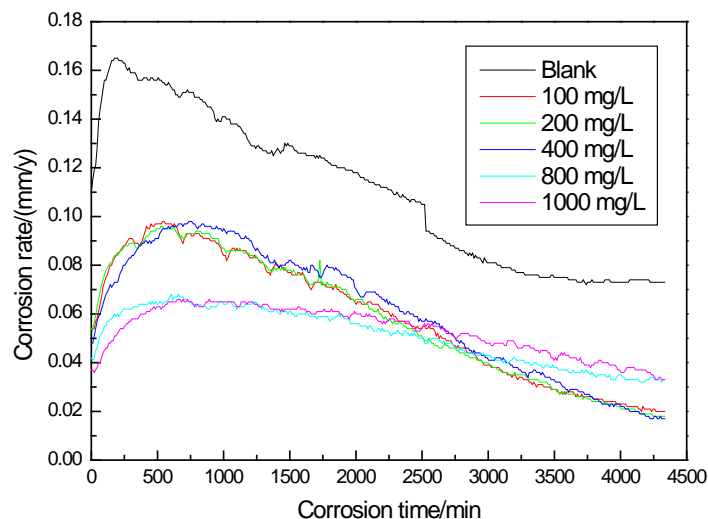


Figure 1. Corrosion Rate of Various Dosage of the Corrosion Inhibitor with Time

The real time corrosion rates of carbon steel in the uninhibited and inhibited blast furnace gas condensed water environments are shown in figure 1. The average real time corrosion rates of the blast furnace gas condensed water contacting the various dosage of the corrosion inhibitor were lower than the average real time corrosion rates without adding the corrosion inhibitor. For the uninhibited system, the corrosion rate increased sharply initially with corrosion time, reaching a maximum of ~ 0.165

mm/y at about 200 min. Further corrosion time was accompanied by a gradual decrease in corrosion rate and tended to be stable at about 2500 min attaining a final value of ~0.087 mm/y. The average corrosion rate of the blast furnace gas condensed water with 100 mg/L, 200 mg/L or 400 mg/L inhibitor all showed better inhibitory performance, with a maximum of ~0.10 mm/y at about 500 min, and then a gradual decrease in corrosion rate and attaining a value of ~0.05 mm/y at 2500 min. The average corrosion rate of the blast furnace gas condensed water with 800 mg/L or 1000 mg/L inhibitor increased with increasing time during the early stages of the testing, which to achieve constant corrosion rate values with ~0.06 mm/y at about 500 min, ~0.05 mm/y at 2500 min and 0.03 mm/y at the end of the test period. While the average corrosion rate of the blast furnace gas condensed water with 100 mg/L, 200 mg/L or 400 mg/L inhibitor was 0.02 mm/y at the end of the test period. So we can add 800 mg/L corrosion inhibitor in the blast furnace gas condensed water and require supplementary inhibitor treatment when corrosion time to 2500 min to prevent corrosion in practical application.

3.2. Corrosion Inhibition Efficiency Evaluated With Weight Loss Method

The corrosion rate and the corrosion inhibition efficiency of corrosion inhibition test results at the different dosages are presented in table 2.

Table 2. The Corrosion Rates and Corrosion Inhibition Behaviour of the Corrosion Inhibitor

Dosage	Corrosion rate (mm/y)	Corrosion inhibition efficiency (%)
Blank	1.624	/
100 mg/L	1.132	30.3
200 mg/L	1.086	33.1
400 mg/L	0.865	46.7
800 mg/L	0.438	73.0
1000 mg/L	0.227	86.0

The corrosion rate decreased with the dosage of the corrosion inhibitor creased from 100 mg/L to 1000 mg/L. The corrosion rate was 0.227 mm/y (corrosion inhibition efficiency was 86.0%) when 1000 mg/L corrosion inhibitor was added, which significantly less than without corrosion inhibitor in the blast furnace gas condensed water. These results implied that the corrosion inhibitor was affective for the corrosion of the blast furnace gas condensed water. This maybe because benzotriazole contained benzene ring and three nitrogen atoms, bonded and lone pair electrons, which were easily adsorbed on the surfaces of various metals and their alloys. A multilayer protective film was formed on the surface of metals, which was hard to dissolve and separate, thus achieving the corrosion inhibition effect of segregation between metal surface and corrosive medium, making the surface of metal without oxidation-reduction, producing no hydrogen, and playing an anti-corrosion role[7].

4. Conclusions

Preparation of the corrosion inhibitor was carried out by adding the benzotriazole in sodium hydroxide solution. The average real time corrosion rates of the blast furnace gas condensed water contacting the various dosage of the corrosion inhibitor were lower than the average real time corrosion rates without adding the corrosion inhibitor. The average corrosion rate achieved constant corrosion rate values with ~0.06 mm/y at about 500 min, ~0.05 mm/y at 2500 min and 0.03 mm/y at the end of the test period under 800 mg/L or 1000 mg/L inhibitor. The corrosion rate was 0.227 mm/y (corrosion inhibition efficiency was 86.0%) when 1000 mg/L corrosion inhibitor was added through weight loss method, which significantly less than without corrosion inhibitor in the blast furnace gas condensed water.

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