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Study on the scale and corrosion inhibitor of urban reclaimed water reused in circulating cooling water of power plant

Xiyang Liu[1,3], Mingxian Geng[2] and Shiyu Zhou[1]

[1] State Grid Jilin Electric Power Research Institute ,Changchun 130021,China;
[2] Changchun Vocational Institute Of Technology ,Changchun 130000,China.

[3] Email: xiyanghaohao@126.com

Abstract. A new type of composite scale and corrosion inhibitor was developed for the thermal power plant circulating cooling water system using urban reclaimed water as supplementary water. Based on the main process parameters of the circulating cooling water system in thermal power plant, a dynamic simulation system is established under laboratory conditions.The new composite scale and corrosion inhibitor and the traditional phosphorus scale and corrosion inhibitor are tested.The results show that the new composite scale and corrosion inhibitor is superior to the traditional phosphorus scale and corrosion inhibitor in scale inhibition and corrosion inhibition.

1. Introduction

At present, the shortage of water resources has restricted the economic development of some areas. The urban reclaimed water has opened up a new kind of water source which can used in industrial.[1] The reuse of urban water for power plant circulating cooling water system is an inevitable trend of future power development, but the composition of urban reclaimed water is complex, and the content of alkalinity, hardness and microorganisms is high. When the traditional phosphorus scale and corrosion inhibitor is applied to the circulating cooling water system with urban reclaimed water [2], System often has scaling and corrosion phenomenon. In severe cases, the condenser vacuum will be reduced, which restricts the reuse of urban reclaimed water to the development of circulating cooling water system in power plant. This paper develops a new type of composite scale and corrosion inhibitor for the circulating cooling water system of power plant with urban reclaimed water reuse. The main component of the composite scale and corrosion inhibitor are PAPEMP, PASP, PAA, PBTCA, the mass fraction is 25%, 20%, 17%, 13%.According to the power plant circulating cooling water system to establish dynamics the simulation test system is used to test the new composite scale and corrosion inhibitor and traditional phosphorus scale and corrosion inhibitor.

2. Test materials and methods

2.1. Test water

The quality and stability of the urban reclaimed water in the northern city of China is analyzed. The urban reclaimed water quality and stability are as follows, see Table 1 and Table 2. It can be seen from the test results that the composition of urban reclaimed water is very complicated, the alkalinity, hardness and microbial content are relatively high. It can be seen from the stability of urban reclaimed water that the fouling tendency is gradually strengthened during the concentration process. When the concentration ratio reaches 3, the water has severe fouling and corrosion trend.The actual operating concentration ratio of the power plant is also close to 3.

Table 1. The quality of the urban reclaimed water.

Project	pH	Cl^-	Total hardness ($CaCO_3$)	Total alkalinity ($CaCO_3$)	Dissolved solids
Numerical value	7.4	242.3	302.2	340.6	428.0
Project	Phosphorus	COD_{cr}	SO_4^{2-}	Ca^{2+}	Mg^{2+}
Numerical value	1.6	16	142.8	59	45

Remarks: except for pH, each project unit is mg/L

Table 2. The stability of the urban reclaimed water.

Water quality	Langelier index	Ryznar index	Puckorius index	Calcium carbonate saturated pH	Calcium sulfate scale index	Larson index
Raw water	Light to moderate corrosion	Medium strength corrosion	Medium strength corrosion	No calcium phosphate scale	No calcium phosphate scale	Medium strength corrosion
3 times concentrated rate	Very severe scaling	Very severe scaling	Severe scaling	Calcium phosphate scale	Calcium phosphate scale	Medium strength corrosion

2.2. Test pieces
Test pieces is A20 steel and 316L stainless steel (surface area: $28cm^2$)

2.3. Test pieces
Dynamic simulation test method is given in the laboratory conditions, the atmospheric pressure saturated steam heating was used to simulate the heat exchanger, The main processes such as flow rate, water quality, flow state, heat transfer intensity, temperature, concentration ratio and water treatment agent addition concentration of the cooling water system of 300WM unit power plant are simulated, [3] through the limit carbonate hardness, corrosion rate, scale analysis comprehensive evaluation of new composite scale and corrosion inhibitor (BJ-509) and the traditional phosphorus scale and corrosion inhibitor (ZS-303) of the corrosion and scale inhibition performance. The WKMZ-II intelligent dynamic simulation experiment device is shown in figure 1.

3. Results and discussion

3.1. Limit carbonate hardness
The cooling water is continuously concentrated during the circulation process.When a certain concentration ratio is reached, the $CaCO_3$ grains in the water are precipitated due to supersaturation. At this time, the total hardness of the circulating water is called the limit carbonate hardness [4]. The addition of scale and corrosion inhibitors is to improve the limit carbonate hardness, Add ZS-303 and BJ-509 respectively to monitor the limit carbonate hardness curve as shown in Figure 2, as shown in the figure, in the same time, the limit carbonate hardness of recycled water added BJ-509 is much higher than added ZS-303, so BJ-509 has a remarkable effect than ZS-303 in the process of preventing the formation of calcium carbonate scale.

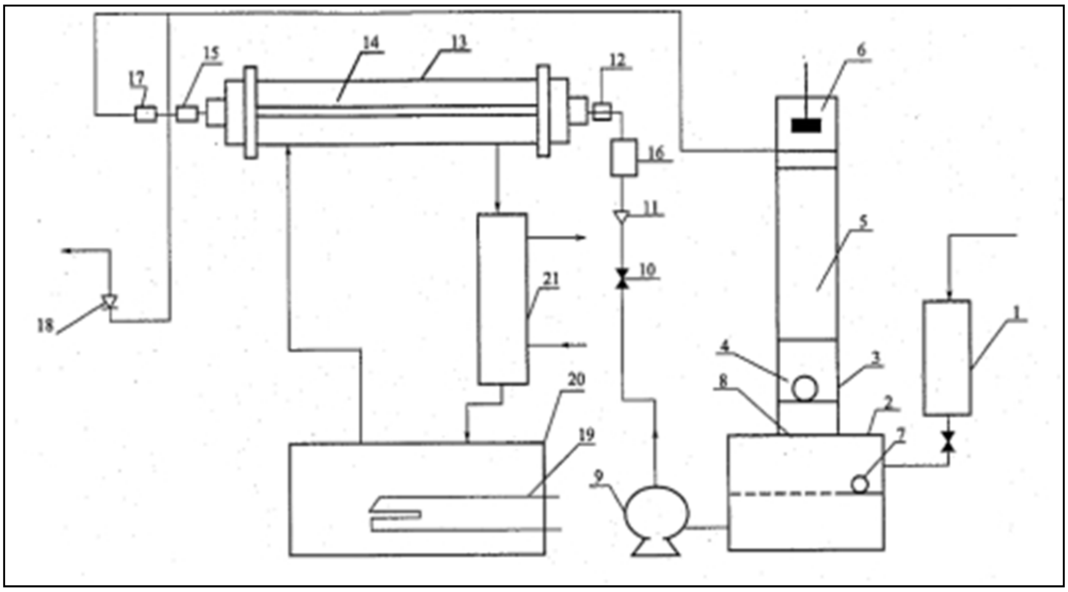

Figure 1. WKMZ - Ⅱ intelligent dynamic simulation experiment.

1. Water supply tank 2. Pool 3. Cooling tower 4. Electric fan 5. packing 6. Axial flow fan 7. Ball float valve 8. Temperature measuring element at the bottom of tower 9, water pump 10. Electric regulating valve and flow sensor 11. Rotor flowmeter 12. Inlet temperature measuring element 13. Simulated heat exchanger.14. Test tube 15. Exit side components 16, 17, hanging cylinder 18. Drain valve and flow meter 19. Electric heater 20. Electric heating 21. Condenser

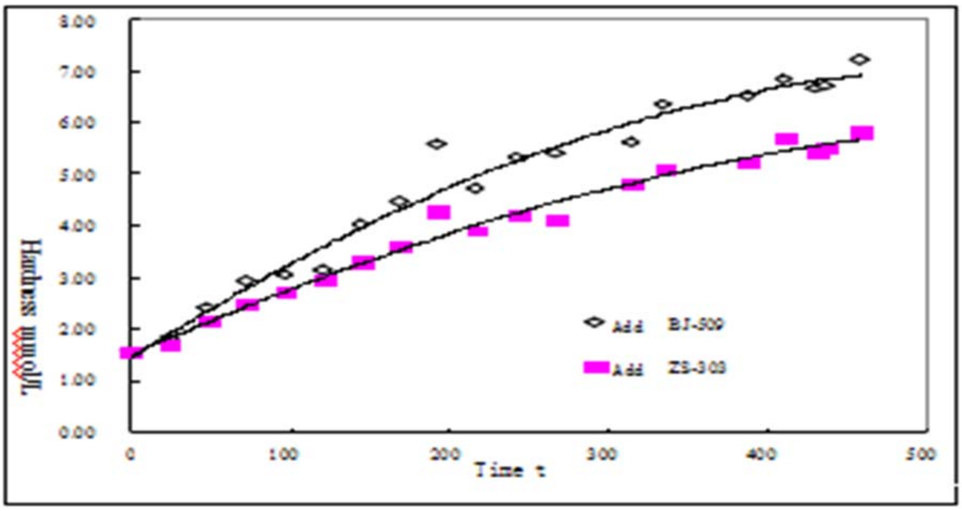

Figure 2. Limit carbonate hardness curve.

3.2. Limit carbonate hardness

The corrosion rate measured by the dynamic simulation test is shown in Table 3. It can be seen from table 3 that the corrosion inhibition effect of the two scale and corrosion inhibitors on the stainless steel test piece is better than that on the A20 steel test piece [5], and the corrosion inhibition effects of the two scale and inhibitors on the stainless steel test piece are basically the same. BJ-509 is superior to ZS-303 in the corrosion inhibition effect on A20 steel test piece.

Table 3. Corrosion rate.

Test strip type	Name	Article I.	Corrosion rate mm/a
A20 steel test piece	ZS-303	Entrance	0.0034
		Export	0.0042
	BJ-509	Entrance	0.0022
		Export	0.0032
Stainless steel test piece	ZS-303	Entrance	0.0001
		Export	0.0002
	BJ-509	Entrance	0.0001
		Export	0.0002

3.3. Scale analysis

The amount of scale in the pipeline added ZS-303 is more than added BJ-509 system. The chemical composition of the scale in the two tests is shown in Table 4. The main components of the fouling are silicate scale and carbonate scale. The scale thermal resistance is shown in Figure 3. With the change of the quality of the circulating water during operation, the hardness of the circulating water and the impurities in the suspended state will gradually deposited in the condenser tube with higher heat load, thus affecting the heat exchange efficiency of the condenser tube, so the thermal resistance of the fouling is more, it is indicated that the more impurities deposited in the condenser tube, it can be seen from Figure 3 that the instantaneous fouling thermal resistance values of the two systems do not exceed 3.0×10^{-4} m^2•K/W[6]. And the thermal resistance of the BJ-509 system is less than the thermal resistance of the ZS-303 system.

Table 4. Chemical composition of scale.

Inhibitor	CaO %	MgO %	SO_3 %	P_2O_5 %	Fe_2O_3 %	Burning reduction%	Acid insoluble matter%	Total amount of scale /g
ZS-303	22.71	9.65	2.83	4.25	3.29	22.98	32.40	0.6969
BJ-509	21.86	8.56	1.19	4.25	2.99	23.12	37.95	0.5062

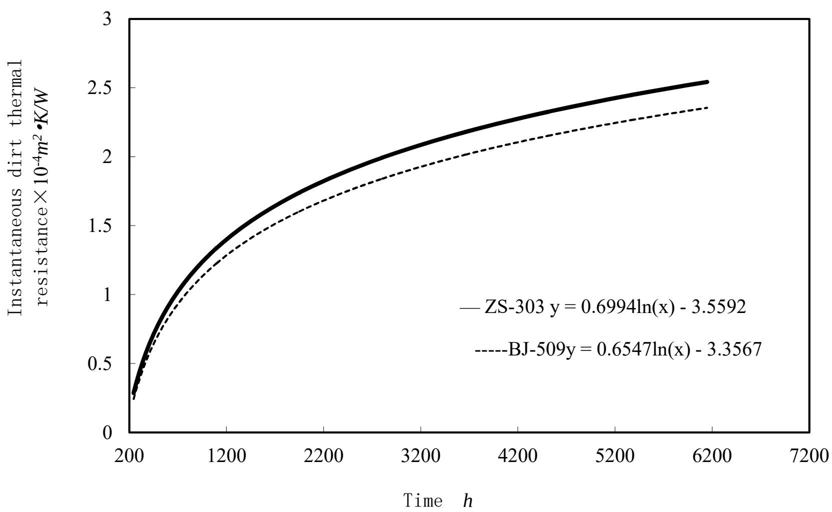

Figure 3. Instantaneous scale thermal resistance.

4. Conclusions

The amount of scale added ZS-303 is larger than added BJ-509. The scale components are silicate scale and carbonate scale. BJ-509 prevents the formation of calcium carbonate scale compared with ZS-303, the effect of the fouling thermal resistance of BJ-509 system is lower than that of ZS-303 system. Therefore, the scale inhibitor BJ-509 has a significant scale inhibition effect compared with the scale inhibitor ZS-303.The corrosion inhibition effect of the two scale inhibitors on the stainless steel test piece is better than that on the A20 steel test piece. The corrosion inhibition effect of the two scale inhibitors on the stainless steel test piece is basically the same,but BJ-509 is superior to ZS-303 in the corrosion inhibition effect on A20 steel test piece.

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