Effect of shot PEENING on Water Vapor Oxidation Resistance of Austenitic Stainless Steel TP347H

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***Abstract*--In order to study the effect of shot peening on water vapor oxidation resistance of austenitic stainless steel TP347H, spare reheater tube of a certain power plant is made into the experimental sample, and part of the samples have been shot blasted, the experimental samples are used to do the contrast test of high temperature water vapor oxidation using a laboratory high temperature steam oxidation device. The oxidation kinetics equations are obtained by oxidation kinetics experiments, results show that in the high temperature steam environment of 800 ℃ within 80h, oxidation kinetics equation of TP347H steel comply with the laws of parabola. oxidation membrane surface and cross-section was analyzed by using SEM, EDX and GIXRD and the results show that shot peening changes the oxide layer of phase composition and the structure of oxidation layer, and significantly improve the oxidation resistance of TP347H steel.**

Keywords--Shot peening; TP347H; oxidation; water vapor

I. INTRODUCTION

In recent years, in order to respond to the country's energy utilization and energy saving policies, Efficient (Ultra) supercritical units have been put into operation, the improvement of unit parameters makes steam oxidation of boiler heating surface temperature increasingly prominent. The oxide films on the inner wall of four boiler tubes (water wall tubes, superheater tubes, reheater tubes, economizer tubes) peel off and block airflow channel causing local overheating tube explosion incidents happen occasionally , and Oxide membrane particles also produce erosion for the steam room components causing abnormal corrosion and wear of turbine blades, nozzles, and impeller bulkhead, which has great threat for the power plant's safety, reliability and economic operation.[1-7] For this reason, companies like Japan NKK firstly proposed that carrying out shot peening and fine grain processing to the inner wall of austenitic stainless steel pipe improve the water vapor oxidation resistance of inner wall.[8-11]

TP347H is the superheater and reheater tubes materials commonly used by power plant. In the experiment, the samples were been shot blasted, and the experiment was carried out through the homemade laboratory high temperature steam oxidation device. After experiment, morphology and composition analysis and research to the oxidized samples been shot blasted and without were carried out. The experiment verifies that shot peening can significantly improve the oxidation resistance of inner wall of TP347H steel pipe.

II. EXPERIMENTAL MATERIALS AND METHOD

A. Sample preparation

The TP347H steel pipe used to the experiment is reheater spare tube of a certain power plant at Zhejiang, the Chemical Composition shown in Table 1, complies with the rules of GB5310-1995 and ASMESA213. Using wire-electrode cutting got a size of 8mm×8mm×4mm cuboid specimens, which were dried in the drying dish after grinded, polished and cleaned, and divided into two equal portions. One of the portion were been shot blasted using pressure of 0.5Mpa and a 60 mesh quartz glass beads. All samples were weighed using Optical Reading Analytical Balances, then subjected to steam oxidation test

TABLE I CHEMICAL COMPOSITIONS OF TP347H STEEL

Element	C	Mn	P	S	Si	Cr	Ni	Nb
Test values	0.07	1.74	0.02	0.008	0.47	17.78	10.13	0.83

B. Experimental device

The self-inventive laboratory high temperature steam oxidation device shown in figure 1, has simple structure, high precision, low cost, high degree of automation. The working temperature of tube furnace used is in the range 0-1300 ℃, controlled by electric temperature controller produced by Japan and single phase SCR power controller, and the error of temperature control is estimated to be ± 1 ℃, Precise temperature control can ensure the stability of the temperature of the reaction zone. The experiments were been deoxidized using the deionized water and purging with nitrogen, the oxygen content in the water could be accurately measured using the oxygen analyzer. Float level controller enables to automatically water from storage bottle to the reaction flask. Because the experimental time is short, and in order to preferably simulate actual working conditions of plants, the rate of oxidation was accelerated ,the experimental temperature was 800 ℃ and the armored digital thermocouple installed could accurately measure the temperature of the reaction zone. The experimental time node were 10,20,40,60,80h.To each time node, the oxidized samples been shot blasted and without were respectively removed and marked, and the samples were weighed in the optical reading dry analytical balance after cooling and drying , then the oxidation kinetics curves were established. The morphology and composition of oxide layer of oxidized samples was analysed adopting FEI Quanta 400 scanning electron microscope made in US and OXFORD INCA X-ray energy dispersive spectroscopy.

III. RESULTS AND ANALYSIS

A. Oxidation kinetics

According to (1), the gain in weight of unit surface area of oxidized sample can be calculated, wherein Wt is the sample's weight at the time of t,Wa is the sample's initial weight,and S is the the surface area.

$$\Delta W = (W_t - W_a) / S \times 10^6 \quad (1)$$

By calculating the increase of weight of unit surface area at each time point , the oxidation kinetics curves can be drawn out. The figure 2 is oxidation kinetics curves that the samples of TP347H steel been shot blasted and without were oxidized to 80h in the steam of 800℃.

Using Origin software fitted the experimental data points obtaining oxidation kinetics equation. The oxidation kinetics equation of TP347H steel been shot blasted is $y=2.3376t^{0.5364}$, and the oxidation kinetics equation of TP347H steel without been shot blasted is $y=4.703t^{0.4383}$,it can be seen that the oxidation kinetics curves comply with the laws of parabola. Contrasting the rate of oxidization gain in weight of samples been shot blasted with the sample without been shot blasted, which shows that shot peening significantly improves the oxidation resistance of steel TP347H

B. Surface morphology of the oxide layer

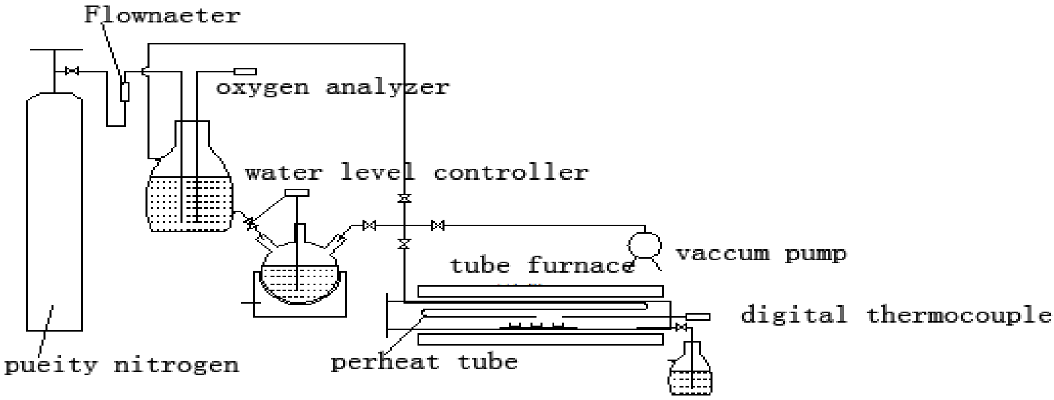


Figure 1. Sketch of high temperature steam oxidation device

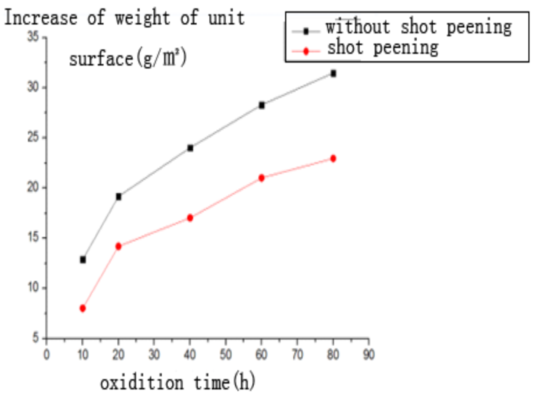


Fig ure 2. The oxidation kinetics curves of TP347H steel been shot blasted and without at the temperature of 800℃

Figure 3 is the Surface morphology of the oxide layer of TP347H steel been shot blasted and without. the sample's surface of TP347H steel without been shot blasted is gray-black, which is an oxide of Fe by XRD analysis results; the sample's surface of TP34H and without. the sample's surface of TP347H steel without been shot blasted is gray-black, which is an oxide of Fe by XRD gray-black, which is an oxide of Fe by XRD analysis results; the sample's surface of TP347H steel been shot blasted is light green, which shows that the oxides of surface are rich in Cr. The surface morphology of TP347H sample without been shot blasted is granular (shown in figure 3a),and the surface is loose; The surface of TP347H sample been shot blasted reserves the "ripple" caused by shot peening, and is more dense. It shows that the more compact the better oxidation resistance, indicating that the TP347Hsteel been shot blasted has better oxidation resistance.

C. Phase analysis of the oxide layer

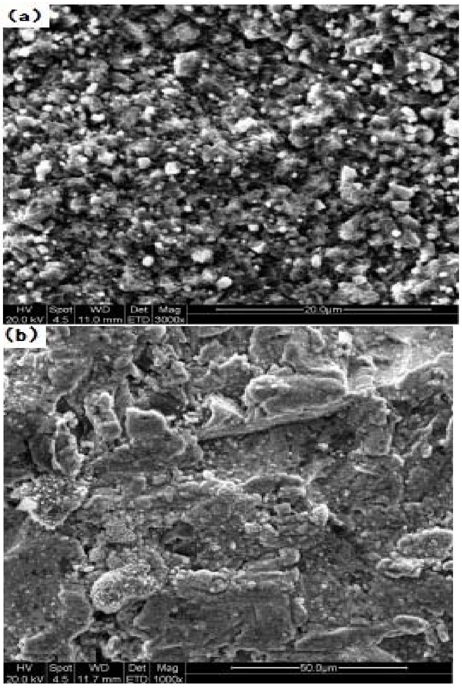
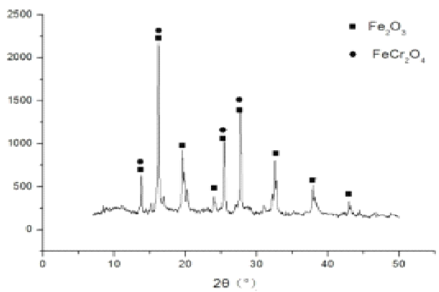
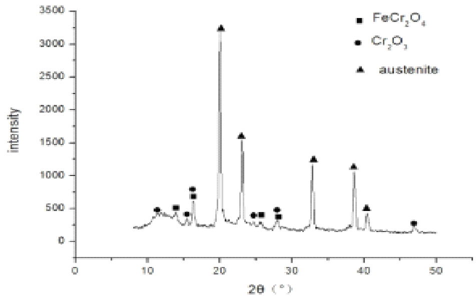


Figure 3. The Surface morphology of the oxide layer of TP347H steel been shot blasted(b) and without(a) which was oxidized to 80h at 800℃

Figure 4 is the XRD patterns of the oxide layer of TP347H steel been shot blasted and without which was oxidized to 80h at 800℃.In order to reduce the diffraction intensity of matrix, the incident angle was 2 °using grazing incidence method. The conclusions obtained by comparing standard PDF card are as follows: the oxide layer of TP347H steel sample without been shot blasted is mainly (Fe, Cr) 3O4 of spinel structure and an amount of oxide of Fe. The oxide layer of sample been shot blasted is mainly Cr_2O_3 and $(Fe,Cr)_3O_4$ of spinel structure.



(a)



(b)

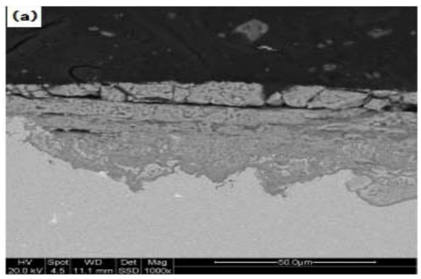
Figure 4. The XRD patterns of the oxide layer of TP347H steel been shot blasted(b) and without(a) which was oxidized to 80h at 800℃

D. Cross-sectional morphology of the oxide layer

Figure 5 is the Cross-sectional morphology of oxide layer of TP347H steel been shot blasted and without which was oxidized to 80h at 800℃. The sample without been shot blasted has been oxidized, the oxide layer has a double oxide structure, and the obvious cracks and holes can be observed; the sample been shot blasted has been oxidized, the oxide layer is a single structure, dense solid , and no stratification.

E. Analysis of cross-Sectional components of oxide layer

Figure 6 is the EDS dot maps of the cross-section of TP347H steel been shot blasted and without which was oxidized to 80h at 800℃, the percentage content of element of each EDS point is shown in table 2、3. It can be seen from Table 2, the content of Cr and Ni is less, Fe and O is high in the outer oxide layer of TP347H steel without been shot blasted, the outer layer is mainly the oxide of Fe, the inner contains higher Cr、Fe、O; the content of Cr is highest in the outermost layer, Cr depleted zone is not observed, the content of Cr, Ni element is more uniform, and the element having greater mutation is also not observed. Through the Distribution of elements and The results of surface diffraction, it can be more sure that the oxide layer been shot blasted is mainly the oxide by the composition of Cr and Fe.



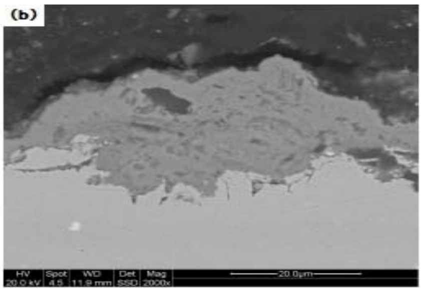


Figure 5. The Cross-sectional morphology of oxide layer of TP347H steel been shot blasted (b)And without (a) Which was oxidized to 80h at 800℃

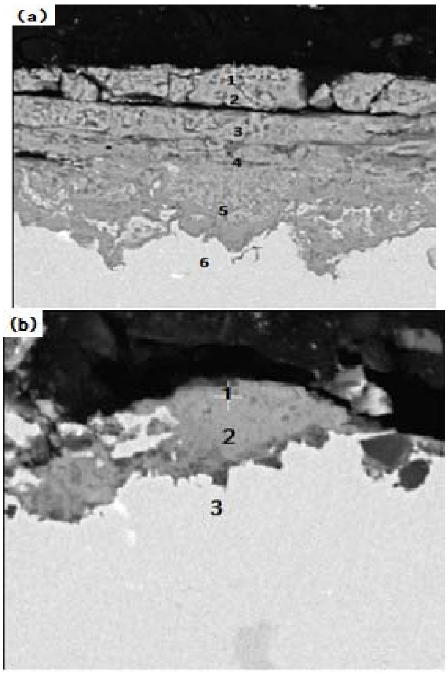


Figure 6. The EDS dot maps of the cross-section of TP347H steel been shot blasted (b)and without (a)which was oxidized to 80h at 800℃

TABLE II. THE RESULTS OF EACH SPECTRUM POINT SHOWN IN FIG.6(A)（AT%）

Atlas	O	Cr	Fe	Ni
1	62.58	0.64	36.37	0.41
2	52.40	1.30	42.19	4.10
3	58.57	1.00	35.15	5.28
4	59.97	16.84	15.03	8.43
5	57.78	16.98	11.92	13.32
6		18.88	69.52	11.60

TABLE III. THE RESULTS OF EACH SPECTRUM POINT SHOWN IN FIG.6(B)（AT%）

Atlas	O	Cr	Fe	Ni
1	46.72	19.36	31.11	2.81
2	63.41	13.85	20.21	2.53
3		17.80	73.79	8.41

III. CONCLUSIONS

1. In the temperature steam environment, at the high temperature of 800℃ within 80h, oxidation kinetics equation of TP347H steel comply with the laws of parabola.

2.Shot peening changes the phase constituting of oxide layer of TP347H steel, greatly improve the Cr content of the oxide layer forming dense Cr, O compound, which inhibits the formation of Fe, O compound, significantly reducing the oxidation rate, improving the oxidation.

3. Shot peening significantly improves the oxidation resistance of TP347H steel, TP347H boiler tube wall after being shot blasted, in which the oxide layer transforms double structure into single structure, in the oxide film has no cracks and holes phenomenon, and the oxide layer is more compact.

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