Formation Causes and Preventive Measures of the Scale of 600MW Unit High Temperature Reheater Tubes

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Abstract. It was found obvious accumulation of scale at the elbow of a high temperature reheaters, by measuring scale accumulation of boiler high temperature reheater SA213-TP347H steel pipe of a power plant. By hardness test, tensile test, optical microscopy and spectroscopy analysis of the pipe sample, it was showed that hardness test results meet DL / T 438-2009 standard requirements; mechanical properties test results meet GB 5310-2008 standards. The microstructure of cross-sectional sample is austenite. EDS analysis result shows that the scale mainly composed of Fe, Cr, Ni oxide. There is obvious stratification in the scale of austenitic stainless steel, the inner layer scale has higher levels of Cr and Ni, Fe and O content is relatively low, which has antioxidant. Fe and O content of the outer layer of skin is relatively high, low Cr and Ni content, leading to its outer oxide does not have the ability of anti-oxidation. There are gathered holes between the inner and outer layers. Temperature change process will produce stress, resulting in oxidation of the outer layer of skin off. Finally, a few precautions to prevent the scale spalling are proposed.

1. Introduction

With the rapid increase in demand for electricity in China and the further improvement of energy conservation and environmental protection requirements, the development of large-capacity, high-efficiency, super (super) critical parameters of thermal power units is the current mainstream trend. [1]. SA-213-TP347H austenitic stainless steel not only has good resistance to intergranular corrosion, high temperature oxidation resistance, creep resistance, but also excellent welding and hot working properties. It has been widely used in domestic supercritical large capacity power station boilers. Compared with the 300MW class or even smaller units, the 600MW class unit reduces coal consumption, but the operating parameters are greatly improved, and the wall temperature margin of the metal material is greatly reduced, especially the boiler superheater and reheater, due to the work. The environmental conditions are harsh, long-term in high-temperature flue gas and high-temperature high-pressure steam, the scale peeling easily causes the tube to burst. The problem of steam oxidation and scale peeling of high-parameter boiler tubes has become a thorny problem faced by the power generation industry at home and abroad. The reason is that the steam oxidation mechanism and the scale peeling mechanism are very complicated and have many influencing factors.

The boiler model of a power plant is DG1900/25.4-II8, superheated steam flow 1900 t/h (BMCR), superheated steam outlet pressure 25.5Mpa.g, superheated steam outlet temperature 571°C, reheat steam
flow 1617.5 t/h, reheat steam. The outlet pressure is 4.46Mpa.g, the reheat steam outlet temperature is 569°C, and the high temperature reheater tube is made of SA-213 TP347H and SA-213 T91. The specification is Φ50.8×4mm. In the measurement of oxide deposits in the elbow of the high-temperature reheater, a total of 17 scales of oxide deposits were found at the bends of the tubes. The results of the radio filming and the sampling results of the cut tubes are shown in Figure 1-2.

2. Test methods and results

2.1. Normal temperature tensile test
The tensile test was carried out on the sampling tube at the site, and the results are shown in Table 1. The tube sample meets the tensile performance requirements of the standard GB 5310-2008.

| Numbering | Yield Strength /MPa | Tensile Strength /MPa | Elongation /% |
|-----------|----------------------|-----------------------|---------------|
| High Temperature Reheater | 345 | 685 | 43.0 |
| requirements of GB 5310-2008 | ≥205 | ≥550 | ≥35 |

2.2. Hardness test
The Rockwell hardness test was performed on the sampling tube, and a total of 4 points were measured. As shown in Table 2, the tube sample meets the hardness requirements of the standard DL/T 438-2009.

| Sample Name | point 1 | point 2 | point 3 | point 4 | average | standard requirement |
|-------------|---------|---------|---------|---------|---------|----------------------|
| High Temperature Reheater | 174 | 166 | 164 | 163 | 167 | 140–192 |

2.3. Microstructure analysis and energy spectrum analysis
The microstructure of the sample tube was observed by a Leica DM 2500 M metallographic microscope. The results are shown in Fig. 3. The microstructure is austenite, and the thickness of the scale is measured. The thickness of the interface oxide is 66.04μm.
In order to understand the change of oxide scale to matrix elements, a line scan was performed using a Tescon VEGA 3 LMU scanning electron microscope. The results are shown in Fig. 4. Among them, red represents the content of oxygen; light green represents the content of iron; yellow represents the content of chromium; purple represents the content of nickel. The oxides were analyzed by Oxford X-act spectrometer to obtain oxides of Fe, Cr and Ni.

3. Analysis and Discussion

It can be seen from the experimental results that the mechanical property test results meet the requirements of GB 5310-2008 standard, the hardness test results meet the requirements of DL/T 438-2009, the metallographic structure is austenite, and meets the requirements of GB 5310-2008 standard. It can be seen that the thickness of the scale is 66.04 μm, and there is significant stratification, and the thickness of the inner layer is about 40.98 μm. XRD experiments were carried out on the scale samples, and as a result, the oxide oxide main components were oxides of Fe, Cr and Ni. It can be seen from the elemental scanning that the content of oxygen increases from the matrix to the outer layer, and the oxygen content of the outer layer is the highest; the content of iron is basically the same as that of the outer layer, and the inner scale is The content of iron element is relatively low; both the chromium element and the nickel element are the same as the inner layer oxide scale and the outer layer oxide is low.

The austenitic stainless steel TP347H has obvious stratification. The content of Cr and Ni in the inner layer is higher, the content of Fe and O is relatively lower, and it has anti-oxidation effect. The content of Fe and O in the outer scale is relatively high, Cr and The low Ni content causes the outer scale to have no anti-oxidation ability, and the aggregated pores will be formed at the interface between the inner
and outer layers. When the scale is deposited to a certain thickness, the temperature will change during the shutdown process. The stress is concentrated, causing the outer layer of the scale to fall off.

The literature [2] pointed out that the main cause of scale formation is high temperature oxidation, in addition to the boiler design structure, operation mode, running time, oxygen content, water quality, high temperature heating surface tube screen geometry, pipe diameter, pipe elbow bending Radius and high temperature are affected by factors such as inlet and outlet pressure difference. There are two main reasons for the spalling of the scale, the scale is formed to a certain thickness, the temperature, pressure and other environmental changes.

4. Conclusion
Based on the above analysis, the scale is oxidized at high temperature and gradually stratified, and the elements in the scale also move, resulting in a decrease in the content of Cr and Ni in the outer scale, an increase in the O content, and an oxide scale in the inner and outer layers. The aggregated pores on the interface cause the scale of the outer layer to fall off easily. Because of the difference in thermal expansion coefficient between the scale and the matrix, when the temperature changes rapidly, there is a large stress, and the oxidation is accumulated to a certain thickness. The skin is peeled off.

The shedding of the scale will bring the following five points to the generator set [3-4]:
(1) It will cause internal blockage of the heating surface of the boiler, causing local overheating of the boiler metal heating surface to burst, especially during the start and stop of the unit, or the load changes too fast during the operation of the unit, the probability of peeling off the scale inside the tube is large.
(2) The scaled scale is carried into the steam turbine by high-speed steam and impinges on the nozzles and blades of the turbine, causing losses.
(3) The peeling scale is deposited between the main valve body of the steam turbine and the valve seat, which may cause the main valve to jam.
(4) The peeling scale will block the water pipe as the condensate flows.
(5) The peeling scale will also cause adverse effects such as deterioration of the steam quality of the unit.

Therefore, the following treatment recommendations for the high temperature re heater problem found:
(1) It is recommended to perform oxide scale cleaning on the pipe cutting tube whose value is exceeded.
(2) In view of the fact that the #2 boiler only runs for one year, there is a relatively obvious accumulation of scale in the lower elbow of the high-temperature reheater. It is recommended that the special inspection of the scale be carried out during each shutdown of the power plant.
(3) It is recommended to strictly control the deviation of the temperature of each tube panel in the cross section of the boiler, strengthen the thermal deviation monitoring and combustion adjustment of the heating surface, improve the distribution of the temperature field of the flue and the heat absorption uniformity of the tube on the heating surface, and effectively reduce the tube of the heating surface. Wall temperature deviation and steam temperature deviation prevent local heating of the heated surface and establish a wall temperature monitoring account.
(4) It is recommended to strictly control the temperature rise and decrease or the temperature drop rate during the start, stop, and rise and fall of the boiler.
(5) It is recommended to strictly control the quality of the feed water and the amount of oxygen added, and strictly check the oxygen content in the thermal system during the oxygen addition process.

References
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