Analysis of cracking causes of micro-spray desuperheater for 1025T/H boiler reheater

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Abstract. A power plant 1025t/h boiler reheater micro-spray desuperheater fixed desuperheating water nozzle tube fillet weld cracking, after inspection and test, analyzed the cause of cracks. The analysis concluded that the welding quality of the end cap of the sprinkler is poor, and the plug weld has a leak point. During the desuperheater operation, the leaked desuperheating water is directly sprayed on the desuperheater cylinder, the fixed stem and the nearby mother. A large number of thermal fatigue cracks are generated under the action of alternating thermal stress, and gradually expand into penetrating cracks under the environment of long-term high temperature and high pressure. In order to avoid the recurrence of similar cracking leakage, it is recommended to replace the failed desuperheater and check the same parts of other desuperheaters and at the same time strengthen the supervision of the desuperheater installation quality.

1. Overview
Spraying water to reduce temperature is a common method in steam temperature regulation of large-capacity boilers. However, due to the temperature of the desuperheating water is much lower than the steam temperature, and the water spray flow is constantly changing, the operating conditions of the desuperheater are bad, the water spray desuperheater often leads to cracking fault. Faults are generally related to alternating temperature difference stress inside the desuperheater [1, 2].

A power plant DG1025/18.2-II 12 boiler reheating steam temperature regulation mainly uses the bezel to adjust the steam temperature, at the same time set up the accident desuperheater and micro-spray desuperheater auxiliary temperature control. Among them, the accident desuperheater is used to protect the reheater system under the accident condition, and the micro-spray desuperheater as the auxiliary regulation means of the reheating steam temperature. Micro-spray desuperheater is mainly used to adjust the vapor temperature deviation and fine-tuning on the left and right.

A side reheater micro-spray desuperheater at the bottom of the spray pipe fixed pipe seat angle weld cracking, as shown in Figure 1. Fixed pipe seat is material 12Cr1MoVG, specifications φ89mm ×9mm, desuperheater material is 12Cr1MoVG, specifications φ609mm×30mm. The structure and cracking position are shown in Figure 2, and the sheet shows that the end cover is a non-fully welded permeable structure with a single side weld.
2. Test analysis results

2.1. Macro inspection

The nozzle is pulled out, the bottom pipe seat angle weld is removed, the macroscopic inspection and the surface flaw detection find that there are two long cracks near the pipe hole and there are dense small cracks in the root of the inner sleeve near the pipe hole, in which the crack 1 length is about 60~70mm and the crack 2 length is about 70~80mm. The cracks showed a reticulated cracking distribution, the crack propagation direction was irregular, and there were branches and secondary cracks, as shown in Figure 3.

The cracks in the inner wall of the cracking part of the fixed pipe seat of the desuperheating water nozzle are larger, the macroscopic view is more tortuous, and there are a large number of small longitudinal cracks nearby, as shown in Figure 4. The fixed pipe seat is planed horizontally according to Figure 5 dotted line, after polishing, it can be seen from the cross section that there are a large number of straight cracks in the inner wall extending to the outer wall, small, different lengths, as shown in Figure 6.
The inspection found that there were two visible leakage points at the end of the water spray pipe, as shown in Arrows 1 and 2 in Figure 7. The two leakage points are distributed approximately 90 degrees along the radius of the end cover, and there is a significant position correspondence with the main crack at the tube hole of the desuperheater. After local amplification, it is seen that two leakage points are located on the weld seam of the end cover and the sprinkler, the edge of the leakage point is more round and blunt, there are scour characteristics, the drawing display end cover is a single side welding of the non-fully welded transmittance structure.

The macroscopic morphology of the nozzle cover is shown in Figure 8, the cover is cut by flame, the edges are irregular and jagged, and the gap size from that of the sprinkler is different, and there are many solder tumors with larger size in various parts of the weld root. A large number of longitudinal cracks are found in the inner wall near the cover of the sprinkler, and the crack expands from the inner wall to the outer wall from the cross section, which are straight and different in lengths.

The cover along the dotted line in Figure 7 from the center of the leakage point along the spray pipe longitudinal incision, polishing, erosion after the leakage point morphology shown in Figure 9, can be seen, the cover and spray pipe gap is relatively large, leakage point 1 between the weld and nozzle, leakage point 2 between the weld and the end cover, leakage point edge due to scour become smooth.
Table 1. Results of chemical composition analysis (wt%).

| Parts or standards                  | Mn  | Cr  | Mo  | V   |
|-------------------------------------|-----|-----|-----|-----|
| The desuperheater                   | 0.58| 1.00| 0.29| 0.16|
| Fixed pipe seat                     | 0.51| 1.00| 0.29| 0.19|
| Fixed pipe seat angle weld          | 0.72| 1.06| 0.57| 0.22|
| Sprinkler pipe                      | 0.63| 1.13| 0.31| 0.23|
| End cover of sprinkler pipe         | 0.48| 0.97| 0.28| 0.18|
| Spray pipe End Cover Weld           | 0.52| 0.98| 0.40| 0.19|
| GB5310-2008 12Cr1MoVG               |     |     |     |     |
|                                    | 0.40~0.70 | 0.90~1.20 | 0.25~0.35 | 0.15~0.30 |
| DL/T869-2012 E5515-B2-V             | ≤0.90| 0.80~1.50| 0.40~0.65| 0.10~0.35|

Table 2. Hardness test Results (HBHV0.5/12).

| Parts                              | Material                                      | Test results |
|------------------------------------|-----------------------------------------------|--------------|
| Base material of fixed pipe seat a | 12Cr1MoVG                                     | 145, 148, 148, 145, 147 |
| Fixed pipe seat angle weld b       | 12Cr1MoVG Matching welding materials          | 168, 175, 170, 173, 171 |
| Base material of sprinkler pipe    | 12Cr1MoVG                                     | 169, 161, 166, 165, 164 |
| End cover of sprinkler pipe        | 12Cr1MoVG                                     | 144, 151, 147, 146, 150 |
| Spray pipe End Cover Weld          | 12Cr1MoVG Matching welding materials          | 203, 205, 201, 206, 202 |

a Refer to DL/T 438-2016 Appendix C: 12Cr1MoVG pipe Fittings 130~197HB
b Refer to DL/T 869-2012, the same steel welded joints which alloy element content does not exceed 3% after heat treatment weld hardness, not more than the base material Brinell hardness value plus 100(HBW), and not more than 270HBW, not less than 90% of the hardness value of the base material.
2.2. Chemical composition analysis
The metal element of the desuperheater, the fixed pipe seat and the angle weld, the sprinkler pipe, the nozzle end cover and the weld seam were tested by Alloy analyzer, and the results are shown in Table 1. The test results show that the element content of the measured material meets the standard requirements.

2.3. Hardness testing
Hardness testing of fixed pipe seat and angular weld, sprinkler, sprinkler end and weld seam using Vickers Hardness meter (test force 0.5kg, keep load 12s, hardness unit HBHV0.5/12), the results are shown in Table 2, the test results meet the standard requirement.

2.4. Metallographic examination
For the metallographic detection of the fixed tube seat (near the weld) shown in Figure 5, the main crack through the crystal expansion, there are a small number of secondary cracks, there are oxides in the crack, and the metallographic structure is Bainite, as shown in Figure 10a and Figure 10b.

The metallographic detection and analysis of the cross section sampling area of the fixed tube seat in Figure 6 shows that the crack is wedge-shaped from the inner wall to the outer wall, the oxidation product exists in the crack, and the metallographic structure is Ferrite + Pearlite, as shown in Figure 10c and Figure 10d.

The two leakage points at the end of the nozzle cover are similar in morphology, and the leakage point 1 is measured by metallographic. Figure 10e shows that the metallographic structure of the cover weld is Bainite, Figure 10f shows that the metallographic structure of the cover base material is Ferrite + Pearlite, and there is no obvious abnormality in the metallographic structure.

3. Analysis and discussion
From the field inspection and test analysis, the crack of the angle weld of the fixed pipe seat is caused by the cracks expand from the inside to outside. There are a large number of cracks in the inner wall near the fixed pipe seat of the desuperheater and the spray tube hole of the desuperheater. There are two leakage points on the weld seam at the end of the sprinkler, and there is a corresponding relationship between the location of the leakage point and the macroscopic crack of the header of the desuperheater.

In the field, no crack defects were found in the non-destructive testing of the fixed pipe seat angle weld and the header of the B-side reheater spraying water desuperheater.

The macroscopic examination shows that the cover itself has poor processing quality and jagged edge, which affects the forming quality of the weld to a certain extent, not only the weld width is different, but the larger size solder tumour has appeared in various parts of the weld root. From the processing and welding point of view, it is no longer possible to rule out the possibility that the cover weld in the manufacturing process already has defects that may cause leakage. The nozzle cover is a hidden part, and the parts in the manufacturing process do not have inspection conditions once assembled [3], and the minor leakage after production will not have obvious consequences in the short term.

The alloy composition, metallographic structure and hardness of the desuperheater header, fixed pipe seat, sprinkler pipe and weld seam meet the standard requirements. The longitudinal cracks of the inner wall are found in the macroscopic and microscopic examination of the specimen, the crack expands from the inner wall of the pipe to the outer wall, and the oxide is present inside the crack, and the macroscopic and microscopic characteristics of the crack accord with the thermal fatigue crack condition [2, 4, 5, 6].

The unit has been running for 14 years, in the micro-spray desuperheater normal operation, desuperheating water and spray pipe temperature difference, will inevitably bring thermal impact to the sprinkler, and thus gradually produce thermal fatigue cracks in the inner wall.
Overall, the nozzle cover processing, welding quality is poor, and can’t be excluded in the manufacturing process there is a possible penetration defects. In the normal operation of the desuperheater, the possible leakage point at the cover has long caused a thermal shock to the fixed pipe seat and the nearby desuperheater header, which has resulted in a large number of thermal fatigue cracks in the corresponding parts of the desuperheater header, the fixed pipe seat and the weld seam, and has been continuously expanded, resulting in a penetrating crack.

Figure 10. Metallographic organizations in various regions.
4. Conclusions and suggestions
Through the detection and analysis, it is concluded that the causes of the cracks in the micro-spray desuperheater of A-side reheater are as: the processing and welding quality of sprinkler cover are poor, and there may be penetrating or near-penetrating defects in the weld seam of the plug cover. In the process of normal operation of the desuperheater, under the repeated action of thermal stress, there are a lot of thermal fatigue cracks in the desuperheater header, fixed pipe seat and angular weld corresponding to the trace leakage point of the weld seam of the sprinkler cover, and the crack gradually expands to form a large leak in the long-term high temperature and high pressure use environment.

To prevent the occurrence of similar accidents, the following recommendations are given:

1. Thermal fatigue cracks are generally mesh expansion, matrix continuity is damaged and difficult to repair, desuperheater to be replaced as soon as possible.
2. The use of maintenance opportunities, focusing on other desuperheater spray pipes for macroscopic inspection.
3. To strengthen the supervision of the quality of desuperheater manufacturing.

References
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