Study on Optimization Control of Hydrogen Sulfide Concentration in Coal-fired Boilers

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Abstract. H2S is an important element to high-temperature corrosion for the water-cooled wall of coal-fired boilers, thus, it is an effective means to prevent high-temperature corrosion through reducing the concentration of H2S near the boiler wall. Since the concentration of H2S in the boiler is closely related to the concentration of O2 and CO, the research on the distribution of H2S atmosphere in the boiler furnace was conducted in this paper. With the air distribution regulation as the means, local O2 concentration is increased, to avoid the accumulation of H2S near the wall and reduce high-temperature corrosion.

1. Introduction
With the development of energy saving and emission reduction technologies, coal-fired boilers have basically achieved low-nitrogen combustion. However, although low-nitrogen combustion technology solves the problem of NOX emissions, it also brings many other problems since the combustion area is often in an oxygen-depleted condition during low-nitrogen combustion. Among them, high temperature corrosion is one of the most important problems [1-7]. Moreover, studies have shown that the high-temperature corrosion of the water-cooled wall in domestic coal-fired boilers is usually sulfide corrosion in a reducing atmosphere, and the corrosion rate is directly proportional to the concentration of H2S in the flue gas. However, the concentration of H2S is directly proportional to the concentration of carbon monoxide (CO) and inversely proportional to the concentration of oxygen (O2). Therefore, reducing the H2S concentration near water-cooled wall of the boiler is an effective means to avoid high temperature corrosion [2].

To understand the wall atmosphere of the water-cooled wall and determine the high-temperature corrosion tendency, the wall atmosphere measurement points installed during the initial shutdown of the boiler are used to test the wall atmosphere of the corresponding water-cooled wall area in the boiler [4]. Meanwhile, under the condition ensuring the normal operating parameters of the boiler, relevant operating adjustment methods are adopted to decrease the reducing atmosphere in the high-temperature corrosion area as much as possible, and suggestions and ideas for transformation are given.

2. Experimental facility
The tested boiler is a steam drum boiler with ultra-high pressure, natural circulation, single-hearth, once intermediate reheat, and balanced ventilation. The exhaust gas pulverizing system was adopted in
the middle storage bin of steel ball mill. The boiler uses low-nitrogen burners arranged at four corners for tangential combustion. After the test boiler passing the low-nitrogen transformation, pipe explosion occurred at the left rear of the water-cooled wall in the furnace during operation, causing abnormal stop of the unit.

There are four layers of primary air and three layers of burning wind (SOFA) in the test boiler, and five layers of flue gas sampling points arranged along the height of the furnace on the four sides of the boiler, namely the front, back, left, and right sides of the furnace (as shown in Figure 1). What is more, two measuring holes are arranged on each floor along the width of the furnace, and there are a total of 40 flue gas measuring holes. In addition, each measuring hole measures the volume fraction of O2, CO, and H2S. The operating evaporation capacity of the test boiler is 410 t/h, namely BMCR working condition.

Figure 1 The layout of the test points in the boiler

3. Experimental results and discussion

3.1. Concentration Distribution of the Smoke Components under BMCR Condition

Under BMCR conditions, the boiler operating parameters are kept basically stable, and the O2, CO, and H2S volume fractions of each measuring hole are measured.

Through analyzing the test results, among the 40 measuring points, the oxygen value of 31 measuring points is 0, showing a strong reducing atmosphere. Moreover, the volume fraction of H2S shows a trend that the left side of the front wall is very low with the height of the furnace, and the left and right sides of the rear wall are high. Therefore, H2S gas can reflect the high-temperature corrosion situation, and the distribution area of high H2S volume fraction obtained in the experiment is consistent with the area that the pipe explosion frequently occurred in the boiler.
### Table 1 Test data under BMCR working condition

| Gas composition | The left of the front wall | The right of the front wall | SOFA | The front of the left wall | The back of the left wall | SOFA | The left of the rear wall | The right of the rear wall | SOFA | The front of the right wall | The back of the right wall | SOFA |
|----------------|---------------------------|-----------------------------|------|----------------------------|--------------------------|------|--------------------------|---------------------------|------|--------------------------|---------------------------|------|
|                | A                         | B                           | C    | D                          | SOFA                     | A    | B                        | C                         | D    | SOFA                     | A                         | B    |
| O₂%            | 0                         | 0                           | 0    | 0                          | 2                        | 0    | 0                        | 0                         | 0    | 0                        | 0                         | 0    |
| CO%            | 2.60                      | 0.95                        | 3.30 | 2.60                       | 2.50                     | 4.20 | 4.30                     | 4.30                      | 7.50 | 3.35                     |                                            |
| H₂S/ppm        | 120                       | 35                          | 109  | 108                        | 72                       | 339  | 360                      | 260                       | 550  | 340                      |                                            |
| O₂%            | 0                         | 0.1                         | 2.4  | 0                          | 0                        | 0.2  | 0.3                      | 2.0                       | 0    | 0                        |                                            |
| CO%            | 2.70                      | 4.30                        | 2.20 | 4.20                       | 4.80                     | 1.06 | 0.80                     | 0.16                      | 4.00 | 3.80                     |                                            |
| H₂S/ppm        | 53                        | 72                          | 83   | 600                        | 710                      | 50   | 51                       | 65                        | 155  | 505                      |                                            |
| O₂%            | 0                         | 0.1                         | 2.4  | 0                          | 0                        | 0.2  | 0.3                      | 2.0                       | 0    | 0                        |                                            |
| CO%            | 8.70                      | 5.20                        | 4.20 | 3.80                       | 4.00                     | 7.10 | 6.40                     | 5.80                      | 8.70 | 3.80                     |                                            |
| H₂S/ppm        | 550                       | 430                         | 160  | 420                        | 450                      | 540  | 600                      | 480                       | 720  | 320                      |                                            |
| O₂%            | 5.6                       | 0.1                         | 0.1  | 0                          | 0                        | 0    | 0.1                      | 0                         | 0    | 0.1                      |                                            |
| CO%            | 1.60                      | 1.30                        | 0.80 | 4.00                       | 5.20                     | 3.60 | 7.00                     | 5.80                      | 7.50 | 4.50                     |                                            |
| H₂S/ppm        | 45                        | 10                          | 8    | 230                        | 540                      | 300  | 530                      | 520                       | 550  | 420                      |                                            |

3.2. Influence of Total Air Volume

By changing the opening of the air supply rotor blades, the total air into the furnace can be controlled, so that the excess air coefficient at the furnace outlet can be changed as well. Therefore, in this paper, the volume fraction distribution of CO and H₂S in the furnace were analyzed by measuring the O₂ content of the provincial boils at the outlet of the economizer and the gas composition at the measuring point.

![Figure 2 Comparison of the burn-out air volume change and the volume fraction of H₂S (ppm)](image)

Under the condition that the NOₓ value of the SCR inlet does not exceed the design value, the air volume at the second layer of the separated burning wind is reduced from 40% to 8%. In addition, since the high H₂S volume fraction area found under the BMCR condition is highly consistent with the area of pipe explosion, only the fourth and fifth layers of the rear wall were tested under this working condition.
Compared with the test results of BMCR conditions, it is found that reducing the volume of the burning wind has a certain effect on reducing the H$_2$S volume fraction in the rear wall area. However, considering the measured value of nitrogen oxide at the SCR inlet, the volume of the burning wind cannot be reduced. Otherwise, NO$_X$ emissions may exceed the standard. Figure 2 shows the comparison of the volume fraction of H$_2$S measured at each measuring point at 8% of the volume of the burning wind and the BMCR condition (40%).

### 3.3. The influence of Operating O$_2$

The air volume at the second layer of the separated burning wind is controlled to be to 8%. Under the premise that NO$_X$ emission does not exceed the standard, other operating parameters of the boiler remain basically unchanged, and the boiler operating O$_2$ volume is gradually increased. In this paper, the volume fraction distributions of CO and H$_2$S under the working conditions of 2.6%, 3.0% and 3.3% O$_2$ are measured.

According to the test results in Figure 3 and 4, with the increase of the operating O$_2$ volume, the CO volume fraction and H$_2$S volume fraction of the atmosphere measuring point on the boiler water-cooled wall generally show a downward trend, and the reducing atmosphere in each water-cooled wall area of the boiler is further weakened, which has a certain effect on alleviating high-temperature corrosion.

**Figure 3** Comparison of CO volume fraction after changing the O$_2$ volume

**Figure 4** Comparison of H$_2$S volume fraction after changing the O$_2$ volume
It will affect the boiler’s efficiency to increase the operating O₂ of the boilers. In other words, the exhaust smoke loss increases, while the loss of incomplete combustion of solid will decrease, affecting the NOₓ emissions. Therefore, when the comprehensive boiler efficiency and NOₓ emissions do not exceed the standard, it is essential to improve the safe operation of the boiler and increase the O₂ content operation as much as possible, which can alleviate high temperature corrosion to a certain extent. Under 410 t/h load, the operating O₂ volume is recommended to be set at 3.3%.

3.4. The Influence of the Air Distribution Form

Under the condition that the boiler maintains an output of 410 t/h, with 3.3% of the operating O₂ volume, and the air volume of the separated burning wind at the second layer is 8%, the secondary air small damper adjustment test is carried out for the areas where the individual CO volume fraction and H₂S volume fraction are prominent.

1. The opening degree of the perimeter air door at each layer is increased from 50% to 80%;
2. The opening degree of the secondary air door at the CD and DD layers of Horn 1 and Horn 2 is reduced from 100% to 90%;
3. The CD and DD layers of corner 2 are reduced to 80%, and the opening at the CD and DD layers of corner 3 is reduced from the original 100% to 90%;
4. The BC layer of Horn 1 is reduced to 80%, the CD layer is reduced to 90%, and the DD layer of Horn 2 is reduced to 90%.

It can be seen from the above test results that the highest volume fraction of H₂S is in the left SOFA layer of the rear wall and the right D layer of the rear wall. Through changing the opening of the small damper at the secondary air, air is added to this area as much as possible to reduce the volume fraction of CO and H₂S in this area. However, it can be seen from the test results that it will actually have less impact on this area without a certain regularity although the different combinations at the secondary air of the small damper are changed. It is believed that this area is affected by the overall flow field of the furnace without sufficient local wind. In addition, the desired effect cannot be achieved by changing the secondary air distribution.

![Figure 5 H₂S volume fraction in the secondary air door test](image)

3.5. The Influence of the pulverized coal quantity

According to the above test data and field observations, there is agglomerating on the upper left side of the rear wall of the boiler, and the reducing atmosphere is strong. Therefore, in this paper, to reduce the thermal load in the upper left area of the back wall of the boiler at No. 4 corner, the combustion tangential circle of the boiler is appropriately shifted to the front wall of the boiler. Moreover, under the condition that the boiler output is 410 t/h, the operating O₂ volume is set at 3.3%, and the air
volume at the second layer of the separated burning wind is 8%, the following two operating conditions are tested.

1. Reduce the speed test of No. 4 horn No. 16 powder feeder.
2. Reduce the CD layer of corner 1 to 90%, and reduce the DD layer of corner 2 to 80%.

| Gas composition | The left of the left wall | The right of the left wall | The left of the rear wall | The right of the rear wall |
|-----------------|--------------------------|---------------------------|--------------------------|---------------------------|
|                 | D                        | SOFA                      | D                        | SOFA                      |
| O₂%             | 0.6                      | 0.3                       | 0                        | 0.1                       |
| CO%             | 5.70                     | 4.70                      | 2.70                     | 2.50                      |
| H₂S/ppm         | 428                      | 564                       | 188                      | 159                       |
|                 | The left of the rear wall | The right of the rear wall |                         |                           |
|                 | D                        | SOFA                      | D                        | SOFA                      |
| O₂%             | 0                        | 0                         | 0                        | 0                         |
| CO%             | 6.10                     | 6.00                      | 4.90                     | 4.20                      |
| H₂S/ppm         | 634                      | 704                       | 507                      | 480                       |

It can be seen from the test results that the above two operation modes have a local effect which is not obvious and does not have certain regularity on the CO volume fraction and H₂S volume fraction on the back wall area.

4. Conclusion
Nowadays, during the operation of the boiler, it is essential to ensure that the nitrogen oxide emission does not exceed the standard, the over-fire air is turned off, and the operating oxygen volume is increased to 3.3%. In general, the CO volume fraction and H₂S volume fraction of the atmosphere measuring points on water-cooled wall of the boil show a downward trend, and the reducing atmosphere in each water-cooled wall area of the boiler is further weakened, alleviating high temperature corrosion to a certain degree. Moreover, it has little effect on the volume fraction domain of H₂S to change the different combinations of secondary air dampers, without a certain regularity. What is more, it has local effect which is not obvious without a certain regularity on the CO volume fraction and H₂S volume fraction on the rear wall area to change the speed of the powder feeder. Therefore, to reduce the high-temperature corrosion caused by the high concentration of H₂S, the most effective means is to increase the O₂ content of the combustion zone as much as possible while ensuring that the NOₓ emission does not exceed the standard. Besides, through reducing the H₂S concentration and CO concentration near water-cooled wall of the boil, it can ensure that the boiler does not affect its normal operation due to high-temperature corrosion storage.

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