Failure analysis of bolt fracture in GGH guide bearing end cover pressure plate in a thermal power plant

Le Chen¹,a*, Song Wang²,b, Yang Xu¹,c and Siyuan Liu³,d

¹Shanghai Institute of Special Equipment Inspection and Technical Research, Shanghai 200062, PR China
²Shanghai Minghua Electric Power Science & Technology Co., Ltd, Shanghai 200090, PR China
³Shanghai Waigaoqiao Power Generation Co., Ltd, Shanghai 200137, PR China
bemail: wangson@spic.com.cn, cemail: forrest313@sohu.com,
demail: lsy@swpg.com.cn
a*Corresponding author email: 742892446@qq.com

Abstract. Gas gas reheater is an important device for waste heat recovery and flue gas purification in thermal power plant. In this paper, the fracture failure reason of pressing plate bolt of guide bearing end cover of flue gas reheater in thermal power plant is analyzed. The results of optical microscope analysis show that there is no obvious abnormality in the metallographic structure of the two guide bearing bolts. The mechanical analysis results show that the hardness value, tensile strength and yield strength meet the requirements of relevant standards. SEM analysis showed that the fracture began at the root of the thread. The research results can provide reference for the operation and maintenance of flue gas reheater in relevant enterprises.

1. Introduction
Energy conservation and environmental protection are the hottest topics in the current energy industry. For thermal power enterprises, waste heat recovery and flue gas purification are the main research directions of energy conservation and environmental protection. According to statistics, the flue gas loss in thermal power plants accounts for more than 80% of the total heat loss of boilers [1]. In the process of flue gas purification, how to effectively recover and utilize the waste heat of flue gas is an important way to implement energy conservation and environmental protection. Rotary gas gas reheater (GGH) is a heat exchange device widely used in flue gas desulfurization system at present. The GGH structure is shown in Fig. 1. Among them, the upper shaft sleeve and the guide bearing seat are fixed by double row centripetal spherical roller guide bearings, and the upper shaft sleeve and the conical surface of the upper main shaft are tightened by the preload of the top pressing plate bolt. The typical structure of guide bearing is shown in Fig. 2. GGH uses the heat of high-temperature raw flue gas before desulfurization to heat the net flue gas after desulfurization, so as to make the flue gas temperature above the dew point, reduce the corrosion of inlet flue and chimney and improve the diffusion of pollutants [2]. At the same time, it can reduce the temperature of flue gas entering the absorption tower and reduce the technical requirements for anti-corrosion in the tower.
GGH is a single unit configuration, and the heat exchange element must operate continuously during unit operation. Failure under high-intensity operation will directly affect the energy consumption index of unit desulfurization system and safe operation of unit [3]. This paper analyzes the failure of a GGH guide bearing end cover pressing plate bolt fracture in a power plant in Shanghai, excavates the bolt fracture mechanism, analyzes the cause of the accident, and puts forward countermeasures, which can provide some reference for GGH operation and maintenance of relevant enterprises.

2. Macroscopic Morphology

The current of GGH drive motor in a thermal power plant increased abnormally. Through on-site inspection, it was found that all three bolts on the top pressing plate of guide bearing were broken, and the broken part was at the root of bolt teeth. Take two broken bolts for failure analysis and record them as No. 1 and No. 2 respectively, as shown in Fig. 3. The bolt diameter is about 32mm and the material is 25Cr2MoVA.

![Figure 3. The broken bolt sample.](image)

The macroscopic morphology of bolt fracture is shown in Figure 4. It can be seen that most areas of bolt fracture are flat and silver gray. Multiple initial steps can be seen at the edge of the fracture, showing a fracture morphology related to stress concentration. The beach pattern with arc distribution
can be seen in the extended area in the middle of the fracture, showing the morphology of fatigue propagation. The fracture surface of No. 1 bolt at 11 o'clock is stepped, as shown in Fig. 4(a). The fracture surface of No. 2 bolt fluctuates greatly near 3 o'clock, which is proposed to be the overload final fracture area, as shown in Fig. 4(b).

Figure 4. Macroscopic morphology of the broken bolt.

3. Results and Discussions

3.1. Metallographic microstructure analysis

Take transverse and longitudinal metallographic samples of No. 1 and No. 2 bolts respectively, grind and polish them, and observe the metallographic structure after corrosion with 4% nitric acid alcohol solution. The metallographic structure is shown in Fig. 5 and Fig. 6 respectively. The metallographic structure is tempered sorbite and bainite, and there is no obvious abnormality in metallography.

Figure 5. Micromorphology of No. 1 bolt.

Figure 6. Micromorphology of No. 2 bolt.
3.2. Metallographic microstructure analysis
Brinell hardness test was carried out on the cross sections of the two bolts respectively. The test force value is 62.5kgf, the indenter diameter is 2.5mm, and the test force holding time is 10s. The test results are shown in Table 1. According to the standard DL/T 439-2018 <The technical guide for high-temperature bolt of fossil-fired power plant>, the Brinell hardness control range of 25Cr2MoVA is 248 ~ 293HBW. According to the results in Table 1, the measured Brinell hardness values of No. 1 bolt and No. 2 bolt meet the requirements of the standard.

| No. | Brinell hardness (HBW) | Average value (HBW) | DL/T439-2018 |
|-----|------------------------|---------------------|--------------|
| 1   | 276/274/279/275/276    | 276                 | 248 ~ 293    |
| 2   | 267/269/269/268/268    | 268                 |              |

3.3. Tensile property analysis
Take the specification from No. 1 and No. 2 bolts as Φ6mm, and the test results are shown in Table 2. According to the standard DL/T 439-2018 <The technical guide for high-temperature bolt of fossil-fired power plant>, the minimum tensile strength and yield strength of 25Cr2MoVA bolt are 785MPa and 686MPa respectively, and the minimum elongation after fracture is 15%. According to the results in Table 2, the elongation after fracture of No. 1 bolt and No. 2 bolt basically meets the standard requirements, and the yield and tensile strength meet the requirements of the standard.

| No. | Yield strength $R_{p0.2}$/MPa | Tensile strength $R_m$/MPa | Elongation $A/%$ |
|-----|-------------------------------|--------------------------|-----------------|
| 1-1 | 825                           | 905                      | 14.0            |
| 1-2 | 834                           | 904                      | 17.5            |
| 1-3 | 822                           | 907                      | 16.5            |
| 1-4 | 838                           | 904                      | 19.0            |
| 2-1 | 777                           | 874                      | 21.5            |
| 2-2 | 803                           | 892                      | 17.5            |
| 2-3 | 823                           | 903                      | 20.0            |
| 2-4 | 791                           | 879                      | 18.5            |
| DL/T 439-2018 | $\geq$686 | $\geq$785 | $\geq$15% |

3.4. SEM Micromorphology analysis
The fracture of No. 1 bolt was cleaned and placed in the scanning electron microscope for microscopic analysis. The low magnification morphology of the fracture initiation area is shown in Fig. 7(a), and the lower side of the figure is the surface of the thread root. It can be seen that the starting area is generally flat, and there are multiple starting steps near the edge. The morphology at high magnification is shown in Fig. 7(b). The visible fracture shows quasi cleavage morphology, and the fatigue propagation striations distributed in parallel are faintly visible.

Figure 7. SEM morphology of fracture initiation zone.
The low magnification morphology of the expansion area in the middle of the fracture is shown in Fig. 8(a). It can be seen that the expansion area is relatively flat and has a beach pattern extending from bottom to top. The morphology at high magnification is shown in Fig. 8(b), and fatigue striations can be seen on the quasi cleavage pattern.

![SEM morphology of middle extended zone](image)

**Figure 8. SEM morphology of middle extended zone.**

The morphology of the final fracture area at low magnification is shown in Fig. 9(a). It can be seen that the final fracture area is stepped and torn. At high magnification, it can be seen that this area is in the shape of tearing dimple, as shown in Fig. 9(b).

![SEM morphology of final fracture zone](image)

**Figure 9. SEM morphology of final fracture zone.**

4. Conclusion
Through macroscopic examination, the fracture of two guide bearing bolts shows obvious fatigue fracture characteristics. The root of thread is a structural mutation, which is easy to produce stress concentration, and fatigue propagation fracture is induced by stress concentration effect. The relative displacement between the shaft sleeve and the bearing end cap will cause the pressing plate bolt to be in a greater alternating tensile state and fail and fracture in a short time.

Acknowledgments
The authors are grateful for the support by Shanghai Bureau of Quality and Technical Supervision Research Project (No. 2021-27).

References
[1] Hu Y., Zhong X.Z., Tian X.J.. (2016) Application of thermoelectric power generation technology in power plant flue gas waste heat recovery. Technology Communication, 8(24): 245-246.
[2] Liang X.J., Zhu W.T., Wei H.G.. (2019) Technical route selection and economic analysis of smoke elimination of coal-fired units. China Power, 52(3): 16-22.
[3] Zhang G.Q.. (2011) Causes and solutions of GGH blockage of desulfurization system in power plant [J]. Friends of Science, 36: 14-15.
[4] Wei S.Z., Wen W.B., Zhang G.X.. (2010) GGH blockage and treatment of desulfurization system in Sanhe power plant. The 14th International Conference on Sulfur Dioxide, Nitrogen Oxide, Mercury, and Fine Particulate Pollution Control Technology and Management.

[5] Kang Z.. (2018) Reasons, preventive measures and optimized solutions for the fracture of the bolts of the guide bearing pressure plate of the air preheater. Low Carbon World, 6: 365-366.

[6] Liu S.T., Zhang L., Cai W.H.. (2018) The technical guide for high-temperature bolt of fossil-fired power plant. Beijing: China National Energy Administration.