Analysis of Causes of Valve Rod Fracture of Steam Turbine High Pressure Main Steam Valve

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Abstract: A 300MW sub-critical coal-fired thermal power plant steam turbine generator set #1 high pressure steam valve stem is fractured. The turbine unit has been running 46000 hours before the crack happened. The chemical component was examined which was in the standard range. They observed the metallographic structure of the broken stem to find the nitriding treatment of fine grain martensite structure at surface area and lath martensite at central section, healthy structure condition. They also found the existing of circumferential oxidized cracks with white corrosion production. According to that, they believe it was caused by residual stress when grinding. Finally, SEM was used to observe the fracture to further confirm our ideas.

1. Introduction

The high-pressure main steam valve of the steam turbine is a protection device for the steam turbine to quickly cut off the steam inlet and stop of the steam turbine. Using pressure oil to control quick shut-off and opening, the off time is less than 0.2s. The high-pressure main steam valve is the most important protection device for the steam turbine to prevent over-speed. The anti-overspeed protection of the steam turbine is also realized by quickly closing the high and medium pressure main steam valves and adjusting the door. Turbine overspeed will cause the shafting fracture turbine to scrape a vicious safety accident and cause serious economic losses[1]. After a cumulative operation of a 300MW subcritical coal-fired generating unit in a thermal power plant for about 46,000 hours, the high-pressure main valve stem broke. In order to analyze and determine the cause of the main steam valve stem fracture, the chemical composition analysis, fracture analysis and metallographic analysis of the fractured stem sample were carried out.

2. Visual inspection

The broken high pressure main valve stem is shown in Figures 1 and 2. It can be seen from Fig. 1 that the valve stem fracture position is $\Phi38$mm and $\Phi49$mm, and the shank is combined with the sharp corner. The fracture is tapered, and the surface oxidation is serious, and the fracture has a long time. There are more regularly arranged circumferential strip cracks on the $\Phi38$mm and $\Phi49$mm rod transition steps, which are more obvious after surface grinding, as shown in Figure 2.
3. Material judgment

The design drawings provided by the manufacturer indicate that the stem material is 2Cr12NiMo1W1V martensitic stainless steel. The surface is treated by nitriding, and the heat treatment is tempered. 2Cr12NiMo1W1V steel is reinforced with 12% Cr martensitic heat-resistant stainless steel. Among them, the alloying elements Cr, W, Mo have a slightly higher content, small notch sensitivity, good shock absorption and anti-relaxation, and good comprehensive performance. [2,3].

The national standard GB/T 20878-2007 stainless steel and heat-resistant steel grades and chemical composition requires that its chemical composition is shown in Table 1. The sample was taken from the end of the valve stem of the main steam valve for EDS spectrum analysis and high-frequency infrared carbon and sulfur analysis. The chemical composition determination results are shown in Table 1. It can be seen from the table that the chemical composition of the broken valve stem is within the standard range and the material is normal.

| GB/T 20878–2007 | C       | Si     | P       | S       | Mn     | Ni      | Cr      | Mo      | W       | V       |
|------------------|---------|--------|---------|---------|--------|---------|---------|---------|---------|---------|
| test value       | 0.21    | 0.2    | 0.03    | 0.025   | 0.86   | 0.81    | 11.46   | 1.08    | 1.05    | 0.28    |

4. Microscopic metallographic analysis

Strip samples were taken at the fractured high-pressure main valve stems A and B (shown in Figure 2) for metallographic analysis. The samples were prepared by sanding, mechanical polishing, chlorination with ferric chloride hydrochloride solution, and then using obsever. The microstructure
was observed by an A1m metallographic microscope, and the microstructure was as shown in Figs.

![Figure 3 circumferential crack at sampling point A](image3)

![Figure 4 Step break at sampling point A](image4)

![Figure 5 Sampling point A away from the fracture](image5)

![Figure 6 circumferential crack at sampling point B](image6)

It can be seen from Figures 3 and 6 that there are circumferential parallel strip cracks on the Φ38mm and Φ49mm rod transition steps, the depth is about 0.1mm~0.25mm, and there are white corrosion products in the crack, indicating that the crack has existed for a long time. Cracks extending along the grain boundaries were not found, and the possibility of temper brittleness due to improper heat treatment was excluded. The matrix structure is martensite, and the surface structure is nitriding surface treatment structure. It can be seen from Fig. 4 and Fig. 5 that the microstructure of the valve stem fracture and the fracture point are all martensite and the tissue is normal.

5. Fracture analysis

Strip samples were taken at the fractured high pressure main valve stem A (shown in Figure 2) for scanning electron microscopy (SEM) fracture analysis. The fractures are shown in Figs.

![Figure 7 SEM picture of the near surface fracture of the sampling point](image7)

![Figure 8 Sampling the SEM picture of the snack section](image8)

It can be seen from Fig. 7 that the color of the fracture near the surface of the fracture site is dim,
and the black fluffy oxidation product adheres to the surface, and the initial texture of the fracture is not seen, indicating that the crack exists for a long time. Figure 8 shows that the core fracture is fresh and has no plastic fracture dimples, indicating that the valve stem is a fast brittle fracture at the late stage of fracture, which is consistent with the fracture characteristics of martensite. No sugar-like cleavage fracture pattern was found, indicating that the valve stem was not brittle along the grain boundary, thus eliminating the situation that the valve stem was tempered and brittle due to improper heat treatment. At the same time, no typical stepped or scalloped pattern of fatigue fracture was found in the entire section [4-7]. It is inferred that the valve stem of the steam turbine high-pressure steam valve of the thermal power plant is gradually reduced due to the existence of pre-crack and continuous oxidation, stress corrosion and expansion, until the critical breaking strength of the material is designed to exceed the critical fracture strength of the material. Expand until the stem is completely broken.

6. Comprehensive analysis and conclusion
After all kinds of hot and cold processing, the material will produce residual stress. The existence of residual stress will have a decisive influence on the performance, dimensional stability, fatigue strength, wear resistance and stress corrosion cracking of the parts [8-10]. Through the above chemical composition, fracture and metallographic test, it is shown that the material of the valve stem meets the requirements and the metallographic structure is normal. It can be seen from the macroscopic analysis that the fracture starts at the sharp corner of the transition step and belongs to the stress concentration part, and there are many regularly arranged circumferential strip cracks on the transition step, which is caused by the surface of the workpiece during the processing. The residual stress exceeds the grinding crack generated by the strength of the workpiece. There are black corrosion products on both sides of the crack, and there are white corrosion products in the middle, which indicates that the surface residual stress further leads to the stress corrosion of the initial crack. Under this comprehensive influence, the crack expands after long-term operation of the steam turbine to form a circumferential shear crack and extends. At the end of the small diameter rod, a conical fracture eventually occurs, so the cause of the fracture is mainly caused by grinding cracks.

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