Analysis of manhole structure Safety of draft tubes in hydropower plant

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Abstract. The fault of the manhole on draft tube in a hydropower plant was investigated and analyzed. The results showed that the main reason for the cracking and leakage of the manhole on draft tube was that: the four corners of the manhole were not rounded, so fatigue cracks appeared under the effect of long-term alternating loads, which caused the leakage at the four corners of the manhole on draft tube during unit operation.

1. Introduction
The draft tube of a hydropower station refers to a pipeline structure that connects the outlet of a turbine runner with the tailwater to make full use of part of the hydropower [1]. The form and size of the draft tube, which has a significant impact on the efficiency of the turbine, are proposed by the turbine manufacturer, [2]. During the maintenance of the unit, maintainers need to enter the draft tube for testing. Therefore, a manhole door needs to be installed on the draft tube to facilitate the access of the maintainers, which involves the opening structure design of manhole on draft tube and the manhole reinforcement, so as to ensure that the manhole strength meets the requirements [3].

2. Detection and analysis
During a certain unit maintenance, the manhole at tailwater was inspected, and it was found that there was cavitation and weld seam cracking on the manhole reinforcement liner, and cracks in the four corners of the manhole at tailwater.

The manhole at tailwater of this unit was a square hole, as shown in Fig. 1. During the inspection, a severe cavitation area with a length of 150mm was found on the surface of the tailwater manhole liner; After the original cavitation site was repaired by welding, the cavitation of different degrees began to appear around the repaired area, as shown in Fig. 2. The fillet welds connecting the liner and the draft tube were detected, one of which had serious cavitation and developed into a crack with a crack length of about 50mm, and the reinforcing plate and the draft tube cracked.
After removing the manhole reinforcement liner, the tailwater manhole was detected, focusing on the four corners of the tailwater manhole. Cracks were detected in three of the four right angles, one of which was a crack in the lower left corner of the tailwater manhole, with a length of about 30mm; There was a crack in the lower right corner of the manhole with a length of about 130mm (Fig. 3). The tailwater manholes of the same type of unit were inspected and similar defects were found. The four corners of the tailwater manholes had different degrees of cracks which caused different degrees of water leakage (Fig. 4).
Troubleshooting revealed that the cracks were mainly concentrated in the four corners of the manhole. The tailwater manhole was a square hole, and there was obvious stress concentration on the square hole at right angles. According to the clause 4.2.1.17 of GB/T 15468-2006 “Basic Technical Conditions of Hydraulic Turbines”, when the square manhole door is used for the draft tube, the four corners should be rounded. The four corners of the tailwater manhole were right-angled, not rounded, so they did not meet the standard requirements. Under long-term cavitation and welding repair cycles, the four corners of the tailwater manholes were rough and uneven, easy to cause local stress concentration.

When the operation conditions of the unit were poor, such as when the unit was being operated in the vibration zone, the draft tube of the unit would vibrate obviously. The draft tube, including the tailwater manhole, was under the alternating load. The unit was put into operation in 1987 and has been in operation for more than 30 years. The alternating stress had been acting on the tailwater manhole for many years. Because the four angles of the manhole were right angles, the stress concentration was obvious compared with other parts, and long-term alternating load effects led to fatigue cracks there.

The stress situation of the tailwater manhole was simulated and analyzed. The element solid185 was used to divide the finite element mesh, with a set internal pressure load \( P_e = 0.2392 \text{MPa} \). The constraint condition was that the top surface around the tailgate was fixed. The hydraulic load surface is as follows:

![Fig. 5 Hydraulic load applied surface of the tailgate](image)

By calculation, the maximum deformation of the structure was 0.4mm, appearing in the middle of the inner panel of the door cover, where the middle of the inner panel was empty, so the deformation was relatively large under the effect of water pressure. The maximum stress was at the contact between the support plate of the manhole seat and the reinforcement liner of the draft cone tube. The results are shown in Fig. 6 and Table 1.

| Thickness | Equivalent stress | Allowable stress (GB/T 15468-2006) | \( P_m \) (ASME) | \( P_l+P_b+Q \) (ASME) |
|-----------|------------------|------------------------------------|-----------------|-------------------|

![Table 1 Calculation results of stress on the tailgate](image)
### References

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