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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.

Fig. 1 External appearance of the tailwater manhole

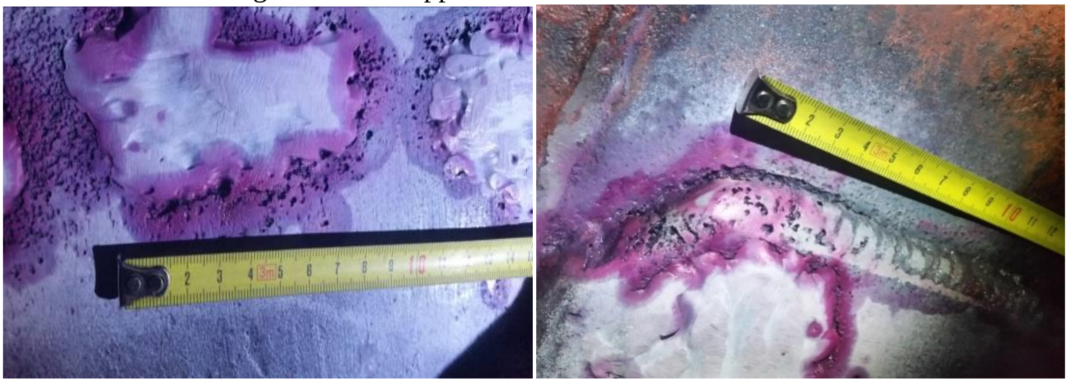


Fig. 2 Cavitation and cracking of tailwater manholes

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).

Fig. 3 Cracks on the tailwater manhole

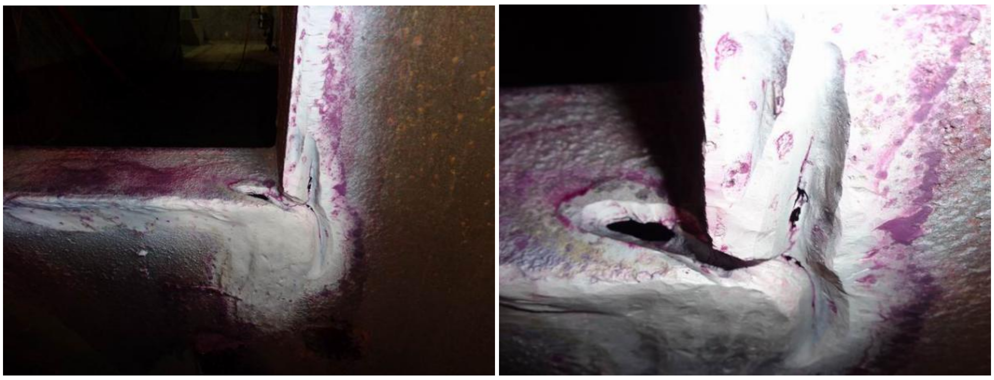


Fig. 4 Cracks on the four corners of other tailwater manholes

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 Pe=0.2392MPa. The constraint condition was that the top surface around the tailgate was fixed. The hydraulic load surface is as follows:

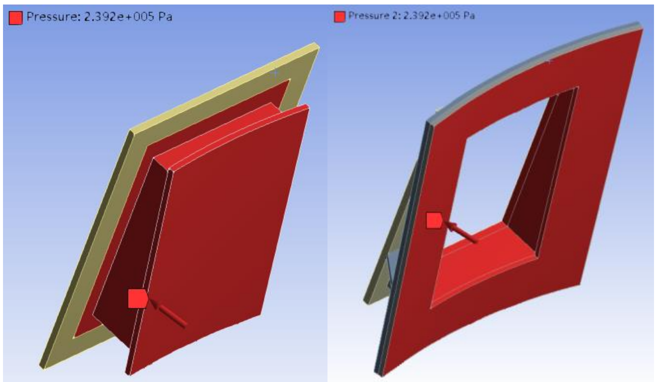


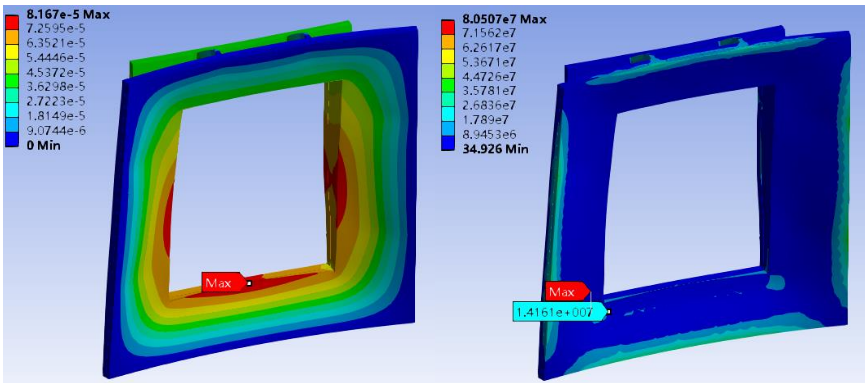
Fig. 5 Hydraulic load applied surface of the tailgate

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.

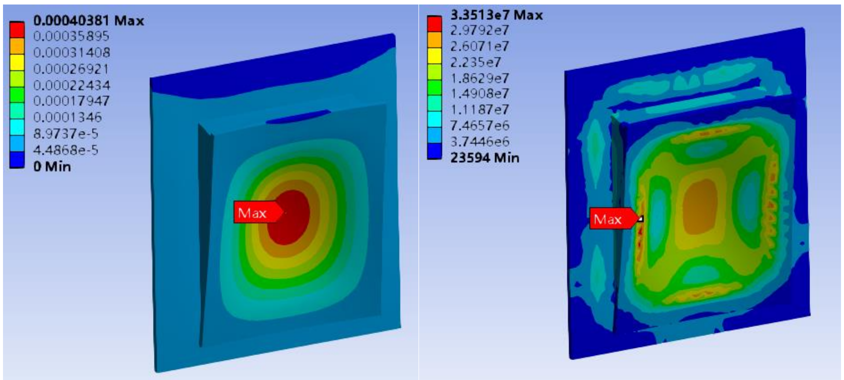
Table 1 Calculation results of stress on the tailgate

Thickness	Equivalent stress	Allowable stress（GB/T 15468-2006）	Pm（ASME）	Pl+Pb+Q（ASME）

Manhole cover	33.5	93.75	150	450
Manhole base	80.5	93.75	150	450
Manhole base (Rounded)	14.1	93.75	150	450



(a) Deformation of the manhole base（b） Stress on the manhole base



（c） Deformation of the manhole cover（d） Stress on the manhole cover

Fig. 6 Finite element calculation results of manhole cover and base of the draft tube

The calculation results showed that the stresses of the entrance door and the entrance seat of the tailwater spinal canal met the requirements of GB / T15468-2006 and ASME. At the right angle of the entrance seat, the stress is small and the safety is high. The rounded corners will further reduce the stress, but the impact on the safety of the entrance door is small [4,5].

3. Conclusions

In conclusion, the tailwater manholes met the standard requirements in terms of structural design, but because the tailwater manholes had been in service for more than 30 years, the draft tube was severely cavitated, the tube wall was locally thinned, and the strength was insufficient. After repeated repair welding due to cavitation, the four corners were not rounded and the surface was rough, which made the local stress concentration obvious and induced crack initiation and propagation.

References

[1] Access Manhole Reinforcement Design for A Penstock, WANG Hong-qiang, YUNNAN WATER POWER,32(3) 70-74

[2] Boundary effect analysis and stress calculation of manhole for steel penstocks in Qiapuqihai hydropower station, TIE Han, xibei water power, 2006(1),30-32

[3] Stress analysis of penstock manhole of Luosheng Hydropower Station, Yang Qiang, Xu Jiang, Feng Jun, Chen Zhangmiao, hubei water power, 2007(5), 8-12
[4] Structural Design of Deeply Embedded Penstock of A Hydropower Project, Zhang Liping, Zhu Yingru, xibei water power 2017(5),36-38.
[5] Design of Penstock for Huangdeng Hydropower Station, Ang Haihong, Guan Zhongrui, Deng Yongjun, water power,2019 (6), 26-30