Analysis of water jetting happened in volute manhole of the hydropower plants

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Abstract. The water injection in the volute manhole of a hydropower plant was investigated and analyzed. The analysis results showed that the main reasons for the cracking and water jetting happened in the volute manhole were that, firstly, the opening of the volute manhole was not reasonable, the reinforcement structure was damaged, and the reinforcement strength was insufficient. Secondly, the welding quality was poor, which caused the weld defect to become a cracking source and expand into a crack.

1. Introduction
The overflowing metal components of hydropower plants guide the water flow and transform the hydraulic force into mechanical force. Once the overflowing metal components are damaged, serious accidents will occur such as unit damage and water flooding of the plant. Among them, large-scale overflowing pipelines mainly include pressure steel pipes and volutes. In order to facilitate maintainers to enter the interior of the overflowing components for maintenance, pressure steel pipes and draft tubes are usually provided with manhole doors [1]. Opening holes in the overflowing pipelines involves the structural design of manholes and the reinforcement of manholes, so as to ensure that the strength of manholes meets the requirements and prevent the occurrence of insufficient strength which will lead to the accidents such as the cracking of the overflowing pipelines and water flooding of the plant [2-4].

2. Detection and analysis
During the operation of a unit, a large amount of water was jetting near the manhole door of the pressure steel pipe (Fig. 1). The operator discovered the situation in time through the industrial television system, and immediately took emergency measures such as stopping the machine, pulling the water inlet gate, pulling the tail water gate, the utilization of water diversion pipe and volute pressure elimination, to control the water jetting.
After the pressure of the volute was eliminated, the volute manhole door was opened for inspection, and the specific location of the crack was determined (Fig. 2 and Fig. 3). The crack started at the right corner of the lower left corner of the square ear hole of the volute manhole, extended about 300mm upstream from the lower left corner of the square ear hole of the volute manhole door shaft pin in the reverse direction of water flow (Zone I), and extended radially about 105 mm along the outer wall of the square ear hole in the door shaft (Zone II).

The defects of the door shaft baffle were cleaned up, and many welding defects were found (Fig. 4). Visual observation showed that the defects were linear, and some of the defects had corrosion products. According to the design drawings, it could be preliminarily determined that the above defects were in the gap between each welding plate. The defects were determined as follows:
1. The gap between the pressure steel pipe and the stiffener. According to the design drawing, the ring width of the reinforcement ring was 270mm. Between the reinforcement ring and the pressure steel pipe, only the edge of the stiffener was welded and fixed. The reinforcement ring and the pressure steel pipe were not completely welded (Fig. 5), so during the polishing process, the gap between the pressure steel pipe and the reinforcement ring was exposed.

2. The gap between the stiffener and the side plate of the door shaft. According to the design drawing, the side plate of the door shaft was welded to the stiffener, without groove in the welding process (Fig. 5). The attachment weld between the side plate of the door shaft and the stiffener was not fully welded, so the gap between the side plate of the door shaft and the stiffener was exposed during the polishing process.

3. The gap between the side plate of the door shaft and the support plate on the door shaft. According to the design drawing (Fig. 6), there was no groove in the welding of the two, and the attachment weld was not complete. The enlarged view of each defect is shown in Fig. 4. According to DL/T 869-2004 “Technical Specification for Welding in Thermal Power Plants”, if the plate thickness is more than 20mm, the one-side bevel cutting process should be implemented at least. Therefore, the welding of each steel plate of the manhole door did not meet the standard requirements.

The position of the crack was inspected in detail, and it was found that the crack on the inner wall of the steel pipe started at the right angle of the square ear hole and was located above the support plate under the door shaft, extending upstream of the steel pipe; The crack position on the outer wall of the steel pipe was located on the support plate under the door shaft after inspection, extending upstream of the steel pipe. Since the crack was a through crack, it could be inferred that the crack started at the right angle to the square earhole.

![Fig. 4 The earhole defect on the door shaft of the manhole](image1.png)

![Fig. 5 Top view of the volute manhole](image2.png)
It could be judged from the extending direction of the crack on the inner wall of the pressure steel pipe that the crack started at the right angle of the square ear hole, which was the stress concentration position. The strength of the pressure steel pipe was decreased after the manhole door was opened, and it was necessary to adopt a stiffener to reinforce the structure of the manhole door. For the stiffener, it was not suitable to make holes in it, otherwise the reinforcement effect would be weakened. The square ear holes of the steel pipe were made on the stiffener and the pressure steel pipe at the same time, which reduced the local strength, resulting in the actual bearing stress on the steel plate around the square ear hole higher than that on the rest of the manhole door [5].

In addition, the quality of the square ear hole was poor, and the form of the square hole led to the obvious concentration of stress on the right angle of the square hole. From the perspective of local strength and local stress distribution, the square hole was an extremely unreasonable form. The manholes doors of other pressure steel pipes of the same type unit were trouble shot, and similar problems were found (Fig. 7 and Fig. 8).

There were two main reasons for the initiation of cracks in the pressure steel pipes: (1) The structure of the manhole door was unreasonable. Making square ear holes in the reinforcement ring not only reduced the reinforcement effect of the reinforcement ring, but also caused stress concentration. (2) The welding quality was poor. The weld between the door side plate of the shaft and the stiffener, and the weld between the side plate of the door shaft and the support plate on the door shaft, were not complete. The local stress was too high, causing the initiation and extension of cracks at the unwelded defect sites.
3. Conclusions
Combined with the above cases, the causes of the crack in the volute manhole were:
1. The volute manhole was made unreasonably, the reinforcement structure was damaged, and the reinforcement strength was insufficient.
2. The quality of the weld was poor, which caused the weld defect as a cracking source to expand into a crack.

The defect in the volute manhole of a hydropower plant could cause a serious accident such as unit damage and water flooding of the plant. Combined with the unit maintenance, the supervisors should conduct non-destructive testing on manholes and the welds around manholes, so as to find defects early. For the manholes with unreasonable structures and damaged stiffeners, repair and replacement work should be carried out in combination with maintenance as soon as possible, to ensure the safe operation of the unit.

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