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Study on Construction Process Technology of Inclined Well in Composite Drilling Method

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Abstract: This paper introduces the construction of a 200.35m deep, 2m diameter, ≤0.5‰ downslope using composite drilling method. In this method, the pilot hole and reaming are constructed with the BMC-D90 directional drilling rig and BMC400 reverse well rig independently developed by Beijing Zhongmei, respectively. During the construction, a wireless while-drilling inclinometer is used to monitor the drilling trajectory of the wellb. The downslope well project was successfully completed under the premise of ensuring construction quality. The successful completion of this project helps to promote the overall project and also provides a reference for implementation of similar projects in the future.

Keywords: Composite drilling method; Downward sloping well; Deflection rate; BMC-D90; Drill bit lifting.

1. Introduction

A pumped storage power station project plans to install four vertical shaft single-stage mixed flow reversible pump turbines with a unit capacity of 300MW, with a total installed capacity of 1200MW and a rated generating head of 354m. Its water supply system consists of two parts: the water diversion system and the tailwater system. The water diversion system buildings include the upper reservoir inlet/outlet, the water diversion tunnel, the water diversion pressure regulating well and the accident gate well, the high-pressure pipeline, the water diversion steel bifurcation pipe, and the water diversion branch pipe. The high-pressure pipeline consists of two upper inclined wells and two lower inclined wells. The depth of the two lower inclined wells is 200.35m, the diameter of the inclined wells is 2m, the inclination angle is 55°, and the deviation rate of the pilot well is required to be ≤0.5‰. Since the through-hole accuracy of the inclined well construction of this project is high and no sharp corners should appear during the correction process, the focus of this project is on the control of the deviation rate of the lower inclined well[1].

2. Project Overview

2.1. Geological Conditions

The upper opening of the lower inclined shaft is located in the Zhongping Cave, and the lower opening is connected to the tailwater system. The surface elevation is 364-435m. The thickness of the rock mass overlying the cavern is 104-171m, and the mountain is strong and there is no thin mountain mass on the side. The surrounding rock of the cavern is micro-neodiorite, with a sub-massive or massive structure and relatively complete rock mass. The fault and joint intensive zone has a moderately steep dip, a small angle with the axis of the inclined shaft, and a large exposure range in the inclined shaft. In addition, the rock mass in the fault and joint intensive zone is broken, which has a great impact on the stability of the surrounding rock of the inclined shaft[2]. There are mainly two groups of fractures, one in the east-west direction and the other in the northwest-west direction (±280°), and most of them are steeply dipped, with a small number of gentle dips and fracture development. The lower inclined shaft section is located near or within the lithological contact zone. The surrounding rock is generally stable, the cave surrounding rock is mainly Class III2, and the rock contact zone with local fault development or thin layer is Class IV.

2.2. Construction equipment

The focus of this project is the control of the inclination rate of the inclined shaft. During the construction period, in addition to closely monitoring the inclination rate of the guide hole, timely correction should be made for the deviation of the guide hole. The construction personnel should have a high level of drilling rig operation and rich field work experience. The design diameter of the lower inclined shaft is 2.0m. In order to ensure the inclination rate and construction progress, the composite drilling method is used for construction. The composite drilling method is a construction process that combines directional drilling and reverse drilling. It is the process method that can maximize the accuracy of the shaft inclination in the current well drilling construction. The composite drilling method described in this article uses the BMC-D90 directional drilling rig independently developed by Beijing Zhongmei. The mud pump model matched with the directional drilling rig is TBW1200/7B. The reverse drilling rig selected is the BMC-400 reverse drilling rig independently developed by Beijing Zhongmei [3], and the TBW850/5B mud pump is selected as the matching one.

2.3. Construction Process

The purpose of reverse well construction is to achieve safety, speed and quality, and the best construction plan is selected [4]. The composite drilling method is a new type of reverse well construction method for deflection rate control. This paper adopts the composite drilling method to construct the lower inclined well. First, a directional drilling rig is used to construct the pilot hole. After the pilot hole is drilled, the drill bit of the directional drilling rig is replaced to enlarge the pilot hole. Then the directional drilling rig is removed and the hole is enlarged. If the pilot hole wall is stable, the integrity is good, and the slag can be returned normally, the pilot hole can

be flushed with clean water. If the slag return is abnormal, mud is required for flushing. The ratio of water to bentonite in the mud is 10:1 [5].

Before construction begins, the installation foundation of the drilling rig is poured with concrete of strength equal to or greater than C20[6]. During the pouring process, it is important to reserve space for the anchor bolts. The purpose of installing the anchor bolts is to fix the drilling rig on the foundation, thereby ensuring the stability of the drilling rig during construction. After the sedimentation tank is excavated, the construction site is arranged. After the directional drilling rig is in place and debugged, the pilot hole is drilled. The diameter of the pilot hole is 216mm. To ensure the accuracy of the pilot hole, the drilling speed is controlled below 1.25m/h[7]. At the same time, the deflection rate of the pilot hole is monitored. Once a deviation occurs, corrective measures are immediately initiated. After the pilot hole is penetrated, the drill rod is retracted, the directional drill bit is replaced, and the second brushing is performed to increase the diameter of the pilot hole to 311mm. The directional drilling rig is dismantled, the anti-hole drilling rig body is installed and debugged, and then the drill rod is lowered, the reaming drill bit is transported to the lower level and installed underground. After installation, the reaming construction is carried out, and finally the inclined shaft with a diameter of 2m is completed. After the hole expansion is completed, the drilling rig is dismantled and the wellhead is sealed. After the wellbore is accepted, all personnel and equipment are removed from the site.

3. Pilot Hole Drilling Construction

Use a directional drill to conduct pilot hole construction. First, connect the pilot hole drill bit and the stable drill pipe with a thread to start the hole drilling operation. During the operation, low drilling pressure should be used to ensure that the drilling pressure is controlled within 3Mpa, the rotation speed is controlled at 20r/min, and the hole is drilled with low torque[8]. To ensure the hole drilling angle, the entire section from the pilot wellhead to the 20~30m section of the wellbore is drilled using a stable drill pipe. After that, the drill is lifted and the drill pipe is rearranged. After that, a wireless downhole inclinometer[9] is installed to monitor the drilling trajectory of the entire well, thereby achieving the purpose of controlling the inclination rate of the inclined well. In addition, the pilot hole accuracy can also be controlled by using a stable drill pipe[10]. The drill rods are arranged from bottom to top according to the guide hole drill bit + joint conversion drill rod + 1 stable drill rod + 4 ordinary drill rods + 1 stable drill rod + 4 ordinary drill rods + 1 stable drill rod + 10 ordinary drill rods + 1 stable drill rod + ordinary drill rod (the quantity is determined according to the depth of the wellbore) until the guide hole construction is completed.

The process of pilot hole drilling is also a process of exploration of the strata[11]. Although directional drilling is not coring drilling, based on the observation of the drilling process and the situation of rock cuttings returned from the wellhead, and referring to previous projects, a preliminary qualitative analysis and understanding of the strata can be made, which provides a basis for hole expansion drilling and well wall support.

Based on the understanding of the geological conditions during the construction of the pilot hole, as well as the amount of slag returned during the construction process and the coarseness of the slag particles, it is judged that the rock breaking roller has entered the fracture zone and mudstone formations. At this time, the circulation volume of drilling mud and clean water should be increased until the muddy part of the fracture zone and mudstone is washed clean, and then the drill rod and drill bit are removed for grouting support. The grouting method can be open hole grouting or drill rod grouting. Drill rod grouting is a more commonly used grouting method that uses the hollow part of the drill rod to spray slurry for grouting by lowering the drill rod. Grouting materials can be concrete, two-liquid cement slurry, pure cement slurry, etc. depending on the situation. After the grouting material in the hole reaches a certain strength, the pilot hole is drilled again until all the broken zones are passed, and then the drill bit is pulled out. After that, the mud concentration is reduced and the whole hole is grouted. This practice is to enhance the stability of the formation and form a water-proof curtain. Under the protection of these safety measures, the pilot hole drilling continues until it is penetrated [12].

4. Hole Expansion Drilling Construction

After the directional drilling rig is dismantled, the hole expansion and well drilling rig is connected to the foundation with anchor bolts, and then various power systems are connected. The well drilling rig is debugged to meet the working conditions, and then the drill rod is lowered, the hole expansion drill bit is installed, and the well expansion construction begins.

4.1. Connection and installation of reamer bit

First, transport the reamer bit to the lower horizontal tunnel, connect the reamer bit to the exposed drill rod with the male cap, and then connect the male cap and the female cap together. The connection process requires the use of a Φ28mm short wire rope. Finally, install the female cap on the reamer bit to complete the connection of the reamer bit. Install the reamer bit to the drill rod. The lower horizontal installation personnel instruct the upper horizontal operator to operate the drilling rig through the wiring telephone, adjust the drill rod to the appropriate angle, and install the reamer bit through the hand winch and the inclined well reamer bit installation base.

4.2. Initial drilling

After the reaming drill bit is connected, notify the upper level to slowly lift the drill bit. Until the roller cutter begins to contact the rock, then stop lifting and rotate at a low speed. At the same time, use just enough force to lift the drill bit to slowly lift it up, ensuring that the drill roller cutter is not damaged by excessive impact. After lifting for a while, stop and wait for the cutter teeth to break the protruding rock. Then continue to lift until the reaming drill bit is completely in the hole. When the hole is just being reamed, a dedicated person must monitor the lower level. If any abnormal situation occurs, the operator must be notified. Only after the drill bit is in the hole can normal reaming and drilling be carried out[13].

4.3. Hole expansion construction

In order to ensure the service life of the drilling rig and the roller cutter, the main pump system pressure is generally limited to within 20MPa during hole expansion to prevent the center tube of the hole expansion drill bit from breaking and falling into the well. During the hole expansion process, when

the rock hardness is large, the drilling pressure can be appropriately increased, otherwise it can be reduced. When expanding the hole, the slag should be removed in time to prevent hole blockage. The hole expansion process is also the process of removing the drill rod. The removed drill rod should be cleaned in time, covered with maintenance oil and equipped with protective caps. If the roller cutter or drill bit needs to be replaced during the hole expansion process, a cordon should be arranged in the protection area of the lower horizontal tunnel, and a safety protection device should be installed to prevent rocks from falling into the hole and injuring people. After the hole expansion is completed, if the hole expansion drill bit is locked by the wellhead, the safety of the wire rope, rails, and hanging caps should be checked first, and then the hole expansion drill bit at the wellhead should be reinforced to prevent the drill bit from falling. After the drilling rig is removed, when the reaming drill bit is lifted away from the wellhead, a dedicated person must direct the lifting work to ensure that the reaming drill bit rises smoothly to prevent the drill bit from deflecting and getting stuck again, thereby damaging the wire rope or lifting cap and causing the reaming drill bit to fall.

5. End of Hole Expansion and Removal of Drilling Rig

When the drill bit expands the hole to 2.5m from the foundation ground, reduce the drilling speed to half of the original speed and reduce the drilling pressure. This is the critical stage of hole expansion. To ensure construction safety, increase the observation frequency and time. Once an abnormality occurs around the wellhead, stop the hole expansion construction immediately, and take timely measures to deal with emergencies and check for safety hazards. Only after safety is confirmed can the hole expansion construction be continued. After the hole expansion is completed, use a Φ20mm short steel wire rope and a steel beam to connect the lifting ring to lock the hole expansion drill bit at the wellhead, remove the auxiliary equipment of the main machine such as the disk crane and drill pipe conveyor, and remove all the oil cylinders and motor oil pipes (except the main push cylinder). Install the drilling rig lifting rod, operate the main push cylinder valve control handle, make the main push cylinder move upward slowly, drive the power faucet upward and slowly lower the main machine. After that, remove the main push cylinder oil pipe and motor cable on the main engine, remove the main engine, operating table, main and auxiliary pump stations, etc., and use a 20t hand-pulled or electric hoist with the lifting anchor above the wellhead to lift the reaming drill bit away from the wellhead. The reaming drill bit must be properly kept after leaving the wellhead. The reaming drill bit is usually placed on a flatbed truck on site, and quickly driven away from the wellhead and transported to a safe area. Two hand-pulled hoists are required to lift the reaming drill bit for descending the inclined well.

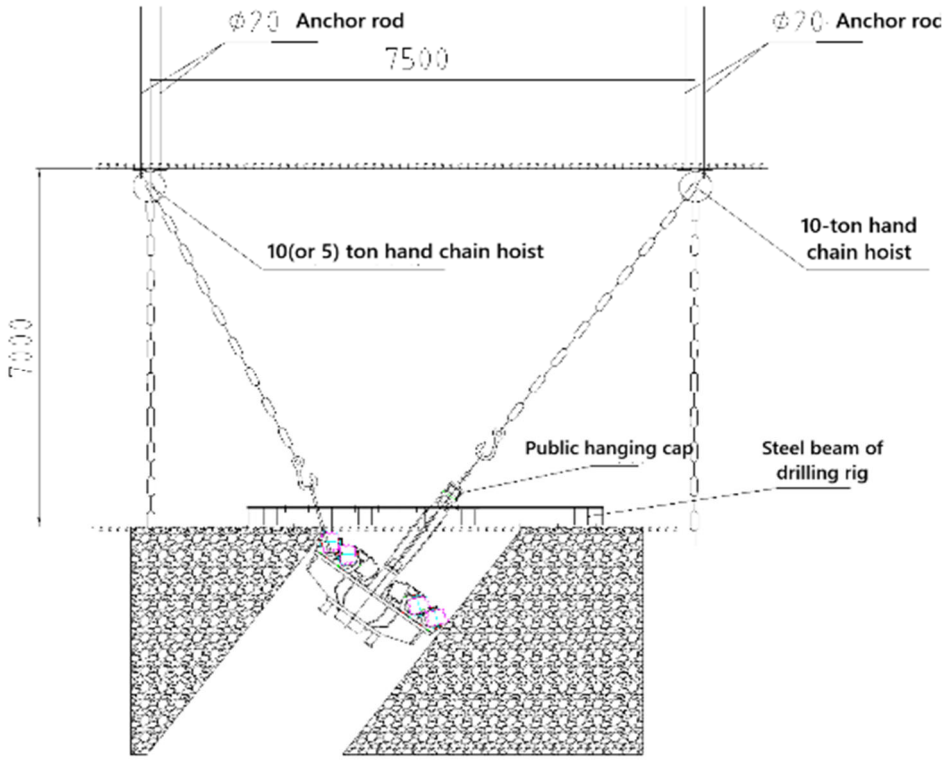


Figure 1. Schematic diagram of the hoisting of the reaming drill bit in the lower inclined well

To ensure that the reaming drill bit and the center of the drill hole are in the same straight line, and to ensure that the reaming drill bit can be smoothly removed from the hole. Figure 1 is a schematic diagram of the hoisting of the reaming drill bit in the lower inclined well.

6. Conclusion

This paper, under the premise of ensuring the safety construction requirements and quality requirements of the project [14], combined with the actual situation on site and taking into full consideration various uncertain factors, successfully completed the construction of the lower inclined

shaft using the directional drilling rig and reverse drilling rig independently developed by Beijing Zhongmei Mine Engineering Co., Ltd. The lower inclined shaft project had a 100% acceptance rate and the shaft deflection rate was ≤0.5‰, meeting the project quality requirements. The construction process of the two lower inclined shafts in this paper was the same, and the construction period of each lower inclined shaft was 55 days. The construction process of the lower inclined shaft constructed by the composite drilling method was scientific and reasonable, and the construction equipment was used appropriately, which greatly improved the construction efficiency and ensured the smooth implementation of the project to a certain extent.

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