Application of Raise Boring Crossing Technology in Domestic Oil and Gas Pipeline Project

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Abstract. In the steep and steep single-sided rocky cliff area, the pipeline can be laid through by using the trenchless crossing method of raise boring, which will change the route selection ideas and principles of the domestic long-distance pipeline industry in the future. Only Saipan Company applied the raised boring crossing technology in Mexico's natural gas pipeline project for the first time abroad, but it has not been applied in the domestic pipeline industry at present, and the related technologies of pipeline engineering have not been studied. This paper introduces the principle and characteristics of raise boring crossing technology and summarizes the construction difficulties of raise boring in oil and gas pipelines crossing mountainous areas by taking the Zunyi-Suiyang-Zheng a natural gas branch pipeline project as an example, which is also the first successful case of raise boring crossing in China. This paper introduces the application of gas transmission pipeline project raise boring crossing technology for the first time, to provide some reference for the popularization of raise boring pipeline crossing technology in the future.

Keywords: Oil and gas pipeline; Mountain area; Raise boring; Pipe laying

1 Introduction

With the rapid development of China's oil and gas pipeline network and the influence of local planning and layout, it is more and more common to build pipelines in mountainous areas. For the single-sided high-steep rock slope with steep terrain, because of the steep mountain and large drop, the bypass scheme with a longer pipeline line or directly laid under the river is generally chosen; if it can't be bypassed, it can only be chopped along the longitudinal slope of the surface. After the pipeline laying is completed, a large number of slope treatment and hydraulic protection projects need to be carried out, which will cause great environmental damage. It is extremely difficult to restore the landform, and it is easy to induce unstable landslides and secondary geo

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logical disasters. When the raise boring technology is applied to the pipeline crossing project, it is especially suitable for the single-sided rocky cliff with steep terrain, which not only avoids the construction cost caused by longer laying lines but also minimizes the impact on the environment as a trenchless crossing method, thus greatly improving the safety of pipeline laying, which will provide a new idea for the line selection of domestic long-distance pipeline industry.

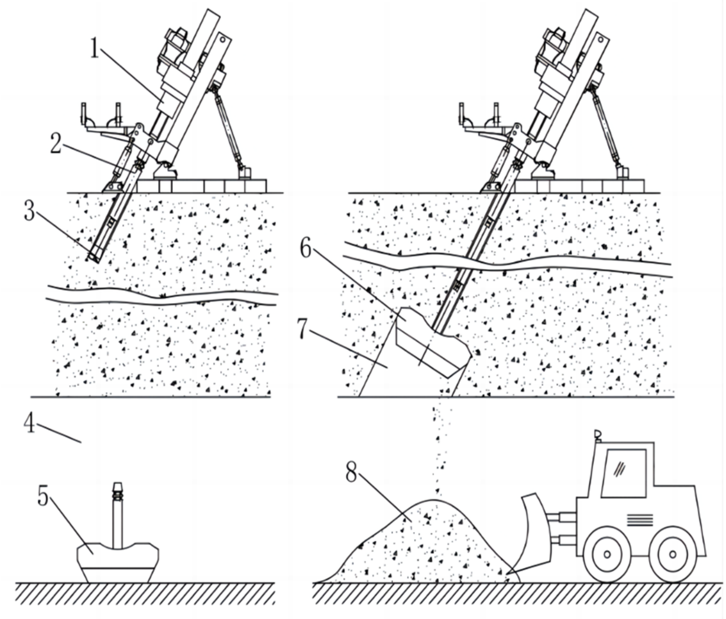
2 Overview of raise boring Crossing Technology

In the 1950s and 1960s, the raise boring rig appeared in the mining engineering field in the United States and Germany. It is a shaft construction equipment formed by combining a tunnel boring machine and a drilling shaft sinking machine and is used for the construction of underground wells, passes, ore bins, and other pilot wells in mines. Up to today, many manufacturers in the world have produced raised boring rigs, the drilling diameter is 0.75～6.0 m, and the drilling depth can reach 900～1,000 m. In China, raise boring has been successfully used in coal, water conservancy, and other industries for more than 30 years.

2.1 Working principle and characteristics of raising boring crossing

The raise boring technology includes two main processes: pilot drilling and reaming drilling, as shown in Figure 1. First, the drilling rig foundation, circulating pool, circulating groove, etc. are constructed at the upper mouth of the reverse well to complete the power supply and water supply (wind) to form a transportation channel, and the reverse well drilling rig is transported in place; the drilling rig is assembled on site and installed on the foundation, the drilling rig orientation is adjusted, the anchor bolts for fixing the drilling rig are poured, the circulating pump and pipeline are installed, the power supply and water source are connected, so that the drilling rig and the circulating pump can operate normally, and the drill pipe, the stabilizing drill pipe and the pilot bit are connected to the drilling rig. Then, we drill the pilot hole from top to bottom, gradually lengthen the drill pipe during the drilling process until the drill bit is connected with the lower horizontal channel, remove the pilot hole drill bit, connect the reaming drill bit, and ream from bottom to top. During reaming, we gradually remove the drill pipe, and the broken rock residue of the pilot hole drill bit is discharged by the circulating pump, and the broken rock residue of the reaming drill bit falls to the lower level by its weight, which is loaded into a transport vehicle by rock loading equipment, transported away from the downhole and reamed to complete the removal of the downhole[1-2].

The main characteristics of raise boring are that mud is not needed to protect the wall during the whole reaming process, and the whole construction area is small. Because of the way self-slag slides, the inclined shaft is vertical and the inner wall of the hole is smooth. The drilling rig has a strong capacity, the diameter of reaming at one time can reach 6 m, and the construction efficiency is high. Raise boring is mainly used in shaft engineering in coal and water conservancy industries and the modified raise boring rig can cross the slope of 30~90. The economic crossing length of raise boring is 300~400 m, and the maximum crossing length should not be greater than 1,000 mm. Due to the equipment capacity of the raised boring rig, the diameter of its crossing section is 0.75~6 m, which can completely cover the laying and application scope of long-distance pipelines [3].



1-reverse drill; 2-drill pipe; 3-guide drill; 4-lower channel; 5-expansion drill; 6-rock hob; 7-reverse drill; 8-broken slag

Fig. 1. Schematic diagram of drilling process: (left) Guide hole drilling, (right) expanded hole drilling

2.2 Operating conditions for reverse well drilling and crossing

The reverse well drilling rig is only suitable for the crossing of Rock Mountain. If there is a soil layer on the surface of the upper hole, excavation should be conducted before construction to ensure that the drilling rig works on the stable rock layer. To ensure the stability of the inclined shaft wall formed by the raised boring rig, the design requires that the strata crossing the inclined shaft section should be within the medium weathering layer; part of the surrounding rock strata passing through the strong weathering layer should be modified and strengthened to ensure the stability of the well wall; adverse geology such as large volume karst cave crossing the formation should be avoided or bypassed [4-5].

2.3 Comparison of reverse well drilling and other crossing modes

In the case of various drilling methods (i.e., steep terrain), the raise boring and other drilling methods are shown in Table 1 [6-8].

Table 1. Comparison table of the advantages and disadvantages of various crossing modes

Through the way	Advantage	Weakness
Excavation through	Range of adapted strata.	(1) It is difficult to carry out ecological restoration and soil and water conservation after the completion of the construction; (2) The slope needs to be protected by hydraulic engineering, with a large amount of work, high difficulty, long cycle, and high cost; (3) All land surface needs to be expropriated, and land acquisition is difficult.
Tunnel through	(1) The tunnel construction technology is mature, and the construction period is controllable; (2) The tunnel space is large, so a pipe can be reserved; (3) It is less difficult to install pipelines in the later stage.	(1) The construction of the tunnel broken surrounding rock section is prone to collapse and roof rise, and there are certain safety risks during the construction; (2) The construction cycle is long and high cost.
Directional drill through	(1) The construction technology is mature, and the construction period is controllable; (2) Compared with tunnels, the cost is lower.	(1) The need for mud, the construction area is large; (2) The construction cycle is long and high cost.
Anti-well drilling through	(1) Once expanded hole, high efficiency and short construction period; (2) The construction land area is small; (3) Back-well drilling construction and pipeline installation are all outside the well, and the safety conditions are controllable.	(1) Only applicable to rock mountains with good integrity; (2) The slope formed is large, which has certain requirements for the later pipeline assembly.

3 Example of the engineering application

3.1 Project Overview

The design pressure of the Zunyi-Suiyang-Zheng'an natural gas branch pipeline project is 10 MPa, and the pipe diameter is D610 mm. Crossing a cliff, the cliff height difference of 128 m, through the horizontal length of about 190 m, belongs to a medium-sized crossing. Crossing the (upper) entrance is about 300 m from the nearest village road, and the exit entrance (the lower entrance) is about 150 m from the nearest cement road. Figure 2 shows the plan of the steep cliff crossing.

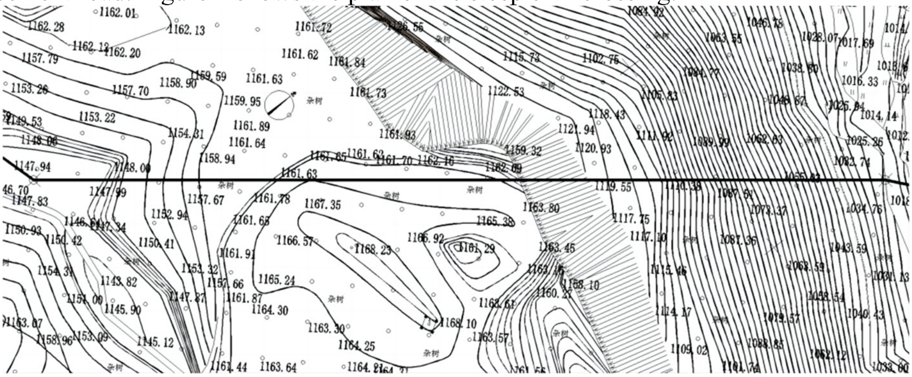


Fig. 2. Plan of steep cliff crossing

3.2 Geological data

According to the regional data, geological mapping results, and site drilling results, the main exposed stratum in the site is the quaternary residual slope (Q4 dl+el) formation and the Silurian Shimanulan formation (S1 hj), and the strata from new to old are described as follows:

(1) Silty clay: yellow ~ yellow-brown, hard plastic, containing a small amount of sand, no shaking reaction, sand soil, broken (block) stone, and a small number of plant roots, broken (block) stone content is about 15%~25%, the general particle size is 10~40 mm, the maximum particle size is 90 mm, local block stone particles, the soil is uneven. In a layer thickness of 0.9~4.0 m.

(2) Strong weathered marl (S1s): yellowish brown, cryptic-microcrystalline structure, layered structure, the main mineral components are calcite, dolomite, quartz, etc., rock mass fragmentation, fissure development, core is short column, block, soft rock, rock RQD value is 10%~30%. In a layer thickness of 6.1~7.4 m.

(3) Moderately weathered marl (S1s): green gray, hidden crystal-microcrystalline structure, layered structure, the main mineral composition for calcite, dolomite, etc., rock is complete-complete, local broken, joint fissure development, core is cylindrical, general column length 50~800 mm, local cave development, with clay soil filling, rock is hard, rock RQD value is 60%~100%. Maximum exposure thickness of 105.2 m.

3.3 Selection of crossing mode

Due to the steep and steep terrain and steep slopes, combined with the advantages and disadvantages of various crossing modes, it is not appropriate to use the crossing mode of excavation and climbing. For the trenchless crossing mode, if directional drilling and tunnel crossing are adopted, compared with the raised boring crossing mode, it has the characteristics of long crossing distance, long construction cycle, and large engineering investment. According to the engineering geological conditions of the steep cliff, the main crossing stratum is moderately weathered marl, with good integrity. Based on the above factors, it is recommended that the solid length of the inclined well is 210 m, the slope is 42, and the solid length of the level tunnel is 25.2 m [9].

3.4 Technical measures for reverse well drilling construction

The crossing angle of this project is 42. According to the rock layer condition, the resting angle of the slag is 35~40, so there is no difficulty in slag discharge. The slag automatically falls along the well wall to the well bottom through its gravity. If the effect of the slag is not good, the slag can be washed into the lower hole by increasing the cooling water of the drill hole. The construction difficulty lies in the precision control of the guide hole deflection and the transformation of the drilling rig for the small-angle construction.

1) The construction method and process: the drilling construction of the reverse well drilling rig is mainly divided into four parts: foundation construction, lower horizontal treatment, guide hole construction, and hole expansion construction. The reverse well drilling rig is arranged at the entrance of the upper hole. According to the site situation, the drilling rig foundation, operation table, main pump station, mud pool, and drill pipe placement area are arranged as shown in Figure 3.

Among them, drilling rig installation and debugging and guide hole drilling process are the key processes, which is the quality assurance of the whole drilling project. The adjustment Angle of the drill is the most basic guarantee of the guide deflection, and the control of the drilling process is particularly important.

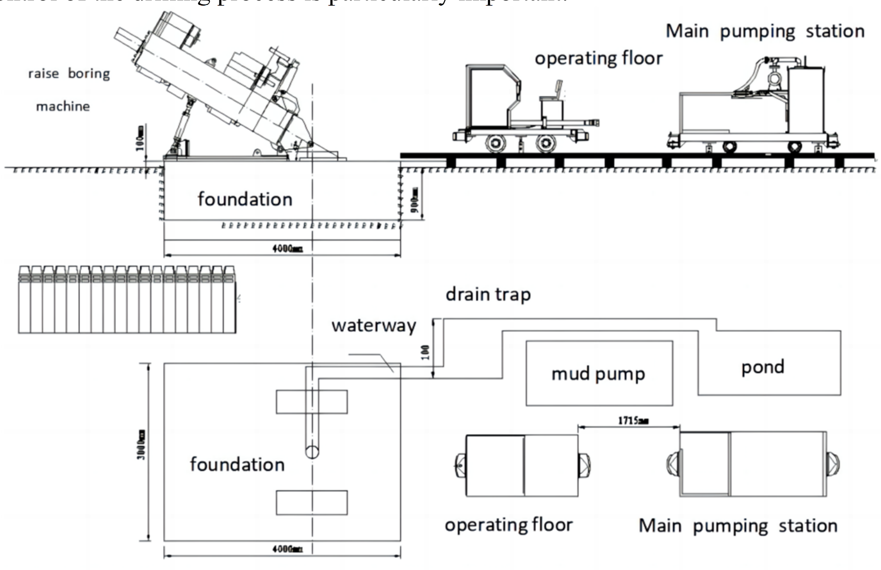


Fig. 3. Layout plan of the construction site of the reverse well drilling rig

The specific construction process is shown in Figure 4.

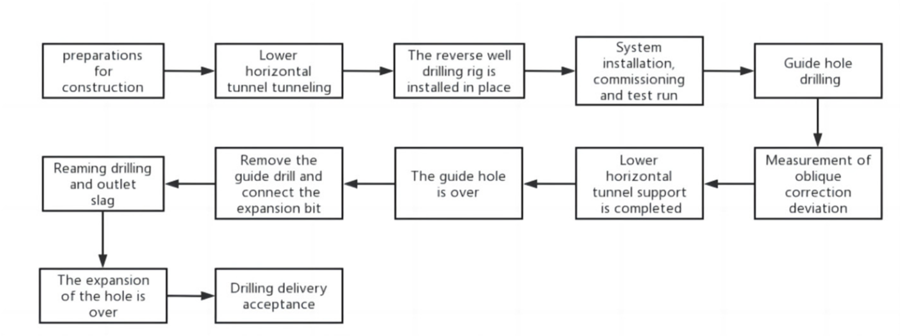


Fig. 4. Flow chart of inclined well guide and expansion construction process

Fig. 5. Backward well drilling site construction

2) Precision control of guide hole deflection.

(1) Deflection control is firstly the positioning and Angle adjustment of the drilling rig, which is directly related to the deflection of the inclined well guide hole. By using the guide hole with a special raise boring rig, the drilling deflection slope is controlled within 0.5‰, and the position of the tunnel in the lower flat lane is accurately driven (see Figure 5 and Figure6) [10-12].

(2) During the drilling process, the wireless drilling goniometer is used to continuously monitor the drilling track, and the deviation is found, and the directional drilling operation is carried out immediately so that the whole drilling track is controlled to meet the design needs.

3) Drilling rig transformation.

At present the domestic reverse well drilling through Angle is more than 60, and the project crossing angle is 42, to adapt to the small Angle inclined shaft work, raising the boring rig must do some transformation design, cancel the rig flat car, design the rig base instead of the flat car, the main hinge position from the drilling frame to the bottom, the purpose is to make the raise boring hole point as close as possible, to ensure the stability of the reverse drill. The lower support is removed and designed as the support form so that the Angle adjustable of the raise boring rig can be increased, not limited to drilling only more than 60 inclined Wells.

Fig. 6. Accurate penetration of the field guide hole

3.5 Technical measures for pipeline laying and installation

There are several remarkable characteristics: large inclination Angle, high efficiency, and no blasting. For back shaft construction, the greater the crossing angle is, the higher the slag production efficiency can be reached; and for pipe installation, the pipe alignment, welding, inspection, and filling [13-15].

1) Construction method and process.

(1) Due to the inclined well crossing Angle is 42, combined with the successful experience of large Angle, the project adopts the top pipe root prefabricated welding, using the top set traction device along the precast pipe to the appropriate position, and then the next pipe welding, so reciprocating construction, finally complete the pipe installation and placement in the inclined well.

(2) For the horizontal section, the 42 hot bending pipe and two straight pipes are first prefabricated into the L-shaped integral pipe section at the bottom of the slope, and then the L-shaped pipe section is transported to the flat section tunnel, and the welding of the inclined well pipe and the L-shaped pipe is completed at the connection position between the inclined well and the flat roadway section.

(3) After the installation of the reverse well drilling through the pipeline, the overall diameter measurement and pressure test shall be carried out. After the above work, the

construction of the bottom of the tunnel shall be carried out first, then the inclined well will be carried out, and finally, the tunnel filling construction of the flat lane section shall be carried out.

The flow chart of the pipeline assembly construction process is shown in Figure 7.

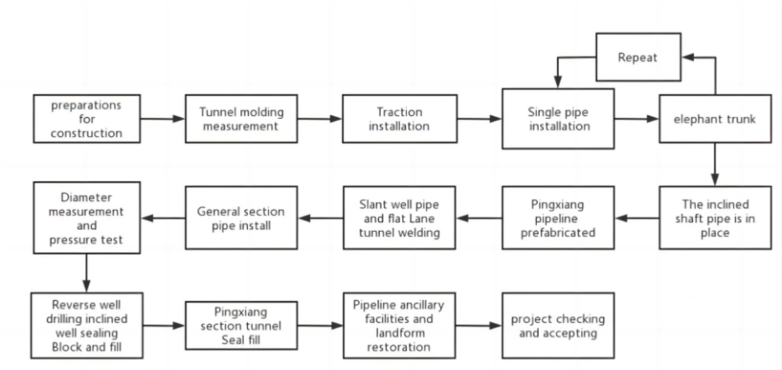


Fig. 7. Flow chart of pipeline assembly and construction process

2) System arrangement and installation of the traction device.

(1) Before the installation of the traction system, it is necessary to design the construction tooling, winch foundation, and fixed pulley foundation in detail, and check the bearing capacity and mechanical performance. After the completion of the tooling, the actual field test should be carried out to ensure reliable performance before it can be put into use.

(2) The winch foundation and fixed pulley foundation adopt the form of a reinforced concrete structure, and the anchor bolts and other embedded parts should be firmly connected with the reinforced concrete structure.

(3) The welding of traction head and pipe shall be operated by the corresponding welding process procedures, and the joint welding joint shall be subject to nondestructive testing and meet the standard.

3) Welding slip pipe.

(1) The first inclined shaft pipe end welding dragged head (including moving pulley), with wire rope on the moving pulley, above the traction equipment (winding) traction release the wire rope, the pipe by its gravity, slowly down the inclined shaft, to the first pipe at the predetermined position to stop and install the hole cover plate.

(2) When the tail end of the first pipe reaches the welding height point, stop the slip pipe, lift the second pipe with a crane, and carry out the welding operation of the first welding joint on the top of the inclined shaft.

(3) After the first and second pipes are welded, the welding track will be cooled, then the nondestructive testing will begin. After the corrosion inspection shall be carried out immediately.

(4) The above process shall be repeated until the pipeline installation in the inclined shaft is completed.

The pipe traction, welding, and slip pipe construction processes are shown in Figure 8.

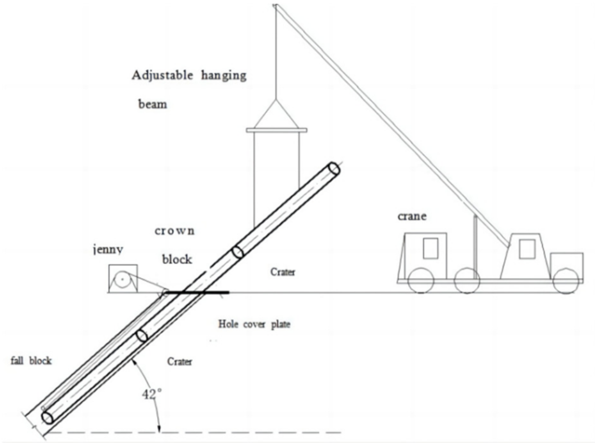


Fig. 8. Schematic diagram of the traction device, welding, and slip pipe

4) Pigging, diameter measurement, and pressure test.

The general line pipeline with a length of at least 50 m on both sides of the crossing section shall be backfilled and checked for overall stress analysis and calculation. After checking, pigging, and diameter measurement, followed by strength pressure test and tightness pressure test. With clean and noncorrosive water as the pressure test medium, the strength test pressure is 15 MPa, and the pressure stabilization time is 4 h, when there is no leakage when qualified. The tightness test pressure is 10 MPa, the pressure stabilization time is 24 h, and a pressure drop is not more than 1% is qualified.

5) Pipeline plugging and filling in the inclined well.

The filling work in the inclined well starts after the pipeline installation is in place. First, 1-meter-thick concrete is used to consolidate the lower part of the inclined well at the bottom, and the distance between the concrete and the surface is at least 0.5 to ensure the growth of vegetation on the surface. After the bottom plugging, the reserved pipeline is used for grouting filling treatment in the inclined well. After the grouting treatment to the top, raw soil is used to consolidate and seal the top, and the minimum spacing between the grouting surface and the ground shall not be less than 1 m.

Due to the existence of fissure water in the inclined well, it is necessary to block the sealing disc at the bottom ring hole. Because the sealing plate cannot be completely sealed with the bottom mouth, the primary treatment is made with cotton wool, cement roll, and cement slurry filling between the tray and the ring space, and then the concrete pouring at the bottom connection, and the pouring thickness is not less than 1 m. The blocking diagram of the bottom ring space is shown in Figure 9.

The difficulty of plugging is related to the water inflow of the wellbore, which is also one of the key processes. The plugging tool uses a double semicircular steel cylinder tray, as shown in Figure 9. The lower cylinder of the tray holds the pipe, and the radius of the upper cylinder of the tray is slightly smaller than the radius of the bare hole. The outer edge of the poured concrete shall not be less than 0.5 m from the wall of the inverted well so that the bearing capacity shall be greater than the height of 10 m and the annular water pressure in the first section [16-17].

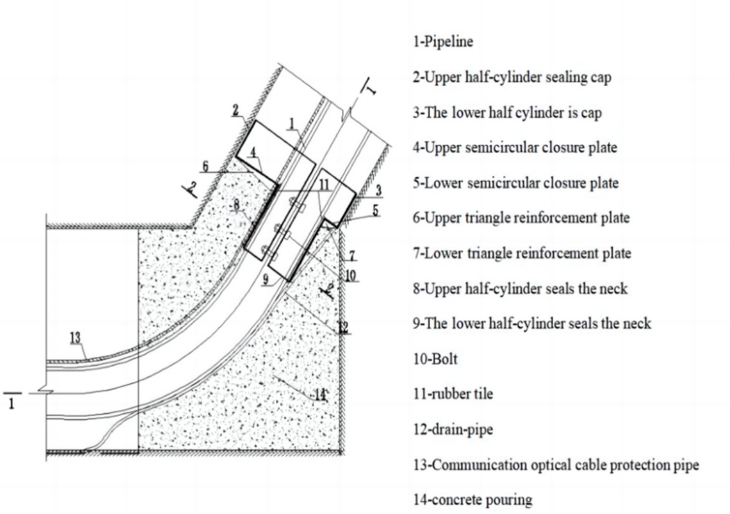


Fig. 9. Section of the bottom ring space

In the initial stage, the bottom of the ring should be stabilized after 2-3 days. Grouting should be filled with cement slurry or fly ash + cement slurry composite material. Backwall grouting filling is the most critical process of the whole reverse well drilling inclined well construction project. The core of the control has two points. One is to keep the pressure balance inside and outside the pipeline as much as possible; the other is the filling quality.

4 Conclusion

As a trenchless crossing mode, reverse well drilling was introduced into the long-distance pipeline industry for the first time, providing a new means to solve the rocky cliffs of mountainous oil and gas pipelines, and making the pipeline crossing mode in mountainous areas more abundant. The Eagle Yan reverse well drilling of the Zunyi-Suiyang-Zhengan natural gas branch pipeline project is the first successful case of anti-oil and gas pipeline crossing in China. This scheme replaces the original 1.5 km tunnel, which not only saves the project cost of nearly 20 million yuan but also saves the construction period of 6 months.

This paper introduces the Rock Mountain reverse well drilling pipeline crossing technology of the oil and gas pipeline for the first time, to provide some reference for the promotion of the reverse well drilling pipeline crossing technology in the future. It is difficult to have a large Angle through the mountain. To achieve the length of the horizontal tunnel at the bottom, which also increases the construction cost and progress of the site. Therefore, small-angle reverse well drilling (10-30) is very important. As the Angle becomes smaller, it will be more and more difficult to control the inclined well deviation and the slag expansion, and further research needs to be done on the subject.

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