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& Gas Hazards Control in Coal Mines

## Research and Application of PDM Borehole Technology for HDD

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### Abstract

By introducing the structure character and working principle of PDM, borehole technologies of PDM directional drilling were studied in this text, including borehole technology principle, directional method, technology flow, drilling technology parameters, branch borehole technology etc. Shaanxi Tingnan Coal .Ltd field application was taken as an example to do a simple introduction on PDM matching equipment and technology promotion. The borehole technology and related result can be used as reference for horizontal directional drilling research and construction.

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*Keywords:* Horizontal Directional Drilling(HDD); Positive Displacement Motor(PDM); Borehole Technology; Branch Borehole

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When PDM is used as down hole dynamical tool in HDD construction, the bent angle and azimuth of the borehole is controlled through angle of tool, which can be adjusted by the bent housing of PDM with the help of measurement-while-drilling (MWD) system, through which the borehole track can be kept along with deserved one, the controlled directional drilling can be realized easily [1]. The directional borehole technology was studied in this paper at the base of analysis of structure and working principle of

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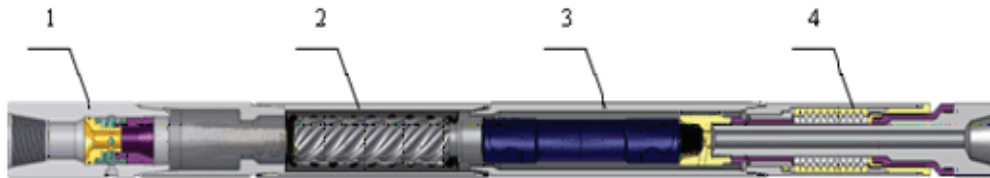
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PDM. The field application of the directional borehole technology was illustrated through a project example at the end of the paper.

## 1. PDM construction

PDM is a kind of positive displacement energy exchange equipment, through which the pressure energy can be changed into mechanical energy. It consists of by-pass valve assembly, motor assembly (it consists of rotor and stator), universal shaft assembly, and drive shaft assembly [2-3]. The construction is shown as Fig1.



1- by-pass valve assembly;2-motor assembly;3-universal shaft assembly;4-drive shaft assembly

Fig.1. PDM construction sketch. The drilling string is still in the PDM directional drilling process, planet motion of rotor around stator is driven by the washing liquor pumped by mud pump through the center hole of drilling rod, a certain pressure difference is generated to rotate the rotor by the changing seal cavity, the rotating speed and torque are transferred to drilling bit through universal shaft and drive shaft to do down-hole drilling.

## 2. PDM borehole technology

### 2.1. Borehole technology principle

0 to 2 degrees of bent housing for PDM are chosen to meet the demand of different HDD application. In the process of drilling construction, the deviation between actual datum and design parameters were compared, the drilling hole can be drilled along with pre-defined axis by drill tool angle adjustment.

The PDM can do directional drilling because of the following three aspects [4]: when PDM is working, drilling bit rotate and break the rock while the housing and drilling rod are still; different bent housings are adapted; the borehole angle of inclination and azimuth can be measured while drilling. Keep the drilling tool angle still, if the ground formation is almost the same, the borehole track can be extended as the desired direction.

### 2.2. Directional drilling method

The bent pipe should be adjusted to the up right through drilling tool angle when the borehole is opened, it is as a reference for directional drilling. The non-magnetic drilling rod and non-magnetic inclination measurement outer housing should be connected behind drilling tools to avoid the electromagnetic interference. The angle of inclination and azimuth can be adjusted through drilling tool angle according to the differences between the borehole track and designed one, controlled directional drilling is realized.

2.3. Technology flow

The process flow of PDM directional drilling is shown as Fig 2.

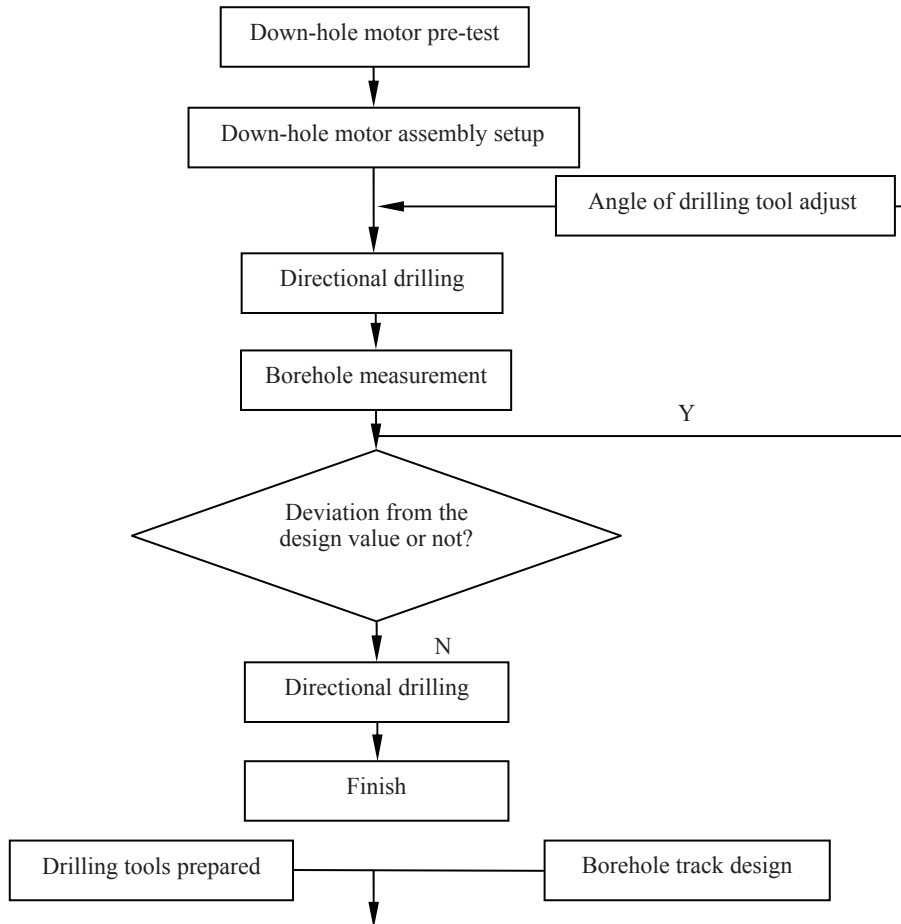


Fig.2. PDM directional drilling technology flowTechnology parameters

The technology parameters for PDM drilling are weight on bit P and pump rate Q. Mud pump can be used as monitor when PDM is drilling, the drilling speed can be adjusted through pump rate, the feeding pressure value can be read from pressure gauge. In the drilling process, the output torque and speed can be controlled from the pump pressure and pump rate of pump. Once the pump pressure increases quickly, PDM should be pulled from the bottom, and pumped with circulating water till the pump pressure is normal, and then apply weight on bit slowly to do normal drilling.

#### 2.4. Measurement while drilling system

Now wire MWD system matching with PDM is commonly used in directional borehole drilling, some parameters like angle of inclination, azimuth, angle of tool, and borehole track can be measured while

drilling, these parameters also can be displayed to instruct drivers to control borehole track.

Directional drilling MWD system is consist of lower non-magnetic drilling rod, measurement probe, top non-magnetic drilling rod, drilling rod with cable go through, water swivel with cable go through, communication cable and orifice monitor. The directional drilling system is formed with the help of the system drilling rig, PDM and drilling bit. The directional drilling system can be used for parameter measurement and track control in nearly horizontal directional drilling, the connection diagram is shown as Fig.3.

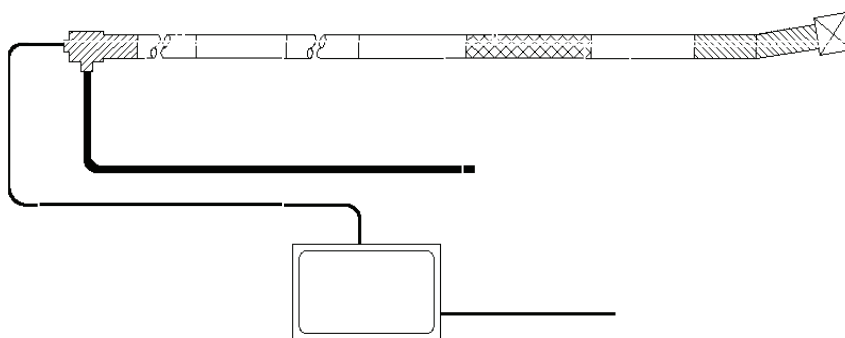


Fig.3. MWD system connection diagram

#### 2.5. Branch borehole drilling from main hole

PDM assembly with bent housing was used to drill branch borehole. Motor assembly should be lowered about 2 meters ahead the branch borehole point, adjust the angle of tool and drill slowly in the motion of sliding till the branch borehole generates.

### 3. Field application

Gas drainage nearly HDD construction in April to May of 2008 for Shaanxi TingnanCoal.Ltd was taken as an example to illustrate the PDM borehole technology.

#### 3.1. Ground condition

The coal seam in construction is NO.8 coal seam of Jurassic stratumYan'an team, which is strip with lination and layer structure, deposit is stable, hard, factor is about 2.0. The coal seam thickness is about 8.0 to 19.6 meters, angle of inclination is zero to 6 degrees. The direct roof is sandy mudstone, thickness is 1.8 meter, brassilcrystal is included, the direct bottom is aluminous mudstone, thickness is 3.1 meter, it is easy to be soft and expansive, which has large effect on drilling borehole construction.

### 3.2. Field test scheme

- Drill site condition

The drill site is located in NO.1 thirl of 113 working face in the coal mine, the traffic is convenient. Water and electricity are supplied sufficient, aeration and water drainage are smooth, The drill site is in rectangle room with dimension of 7.0×5.0×4.0 meter, the room roof and side are all protected with net and spouting, the frontal should be steady and flat.

- Borehole placement

NO.1 borehole is designed parallel to NO.113 working face haulage roadway, the angle of borehole opening inclination is minus 2.3 degree, azimuth is 147.5 degree, the borehole opening diameter is 153 millimeter, final borehole diameter is 96 millimeter. The angle of borehole opening inclination for NO.2 is minus 3.8 degree, azimuth is 147.5 degree, borehole opening is 153 millimeter, final borehole diameter is 96 millimeter. The angle of inclination and azimuth can be adjusted along with ground condition.

- Drilling tools choice

Drilling tools mainly include:  $\phi 73\text{mm}$ PDM with 0 to 2 degree adjustable bent housing,  $\phi 73\text{mm}$ PDM with 1.25 degree adjustable bent housing,  $\phi 73\text{mm}$  drilling rod with cable go through,  $\phi 153\text{mm}$ reamer bit and  $\phi 153\text{mm}$  PDC bit.

- Drilling technology parameters

In normal drilling, the pump rate of pump should be controlled in 160 to 250 L/min, drilling feeding force should be controlled less than 1.5 times of biggest pressure differential for PDM, average drilling speed should surpass 13.5 m/h.

### 3.3. Construction introduction

Field drilling last for 27 days, two main borehole were drilled, 4 side-tracked branch holes were drilled, total footage was 2402 meters. Final depth of NO.1 main borehole was 1046 meters, which is the deepest record for nearly horizontal directional drilling, NO.1-1 and No.1-3 branch holes were drilled separately in core seam and coal seam, target in tunnel were both hit. Final depth of NO.2 main borehole 822 meters, target in tunnel was hit by NO 2-1 in the left direction, drill site and borehole track diagram were shown in Fig.4.

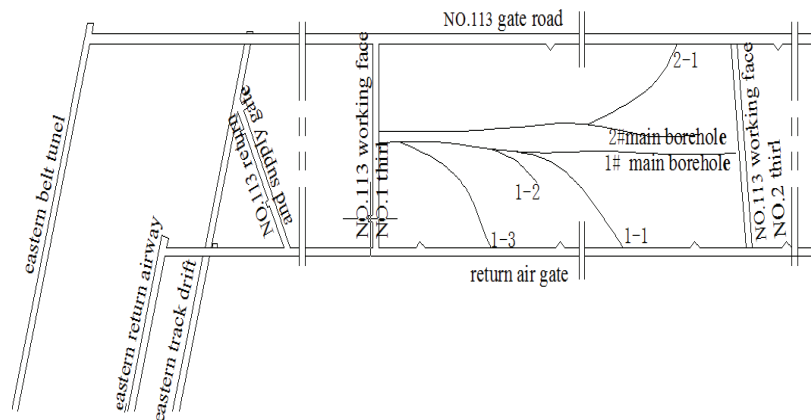


Fig.4. Drill site and actual borehole track diagram

#### 4. Promotion

System analysis, lab test, field industrial test and some improvements have been made on PDM and related equipments, which has been promoted with process technology. The equipment and process technology has been promoted for 50 sets till the end of year 2010. The total output value has reached 0.5 billion RMB, the total footage has surpassed 250 thousand meters. The project has gained two NO.1 prizes named as China Coal Industry Association Technological Invention Award and Shaanxi Province Technological Invention Award. It has great meaning for directional borehole construction in coal mine gas drainage.

#### 5. Conclusions

- Mud pump can be used as monitor when PDM is drilling, the drilling speed can be adjusted through pump rate, and pump pressure can reflect the borehole condition.
- MWD system is matched with PDM, angle of tool can be adjusted to control the angle of inclination and azimuth, directional drilling is realized and location can be accurate.
- Directional drilling can be realized by PDM, the side-tracked branch holes also can be drilled to enlarge the borehole coverage areas, gas drainage and ground exploration efficiency are raised.

#### Acknowledgements

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