Analysis and Application of Treatment Techniques in Horizontal Directional Drilling Borehole Accident

Haitao Mo*, Zhijun Shi, Shijun Hao, Quanxin Li

Xi’an Research Institute of China Coal Technology & Engineering Group Corp, Xi’an, 710077, China

Abstract

Based on the analysis of the borehole accidents regularly happened in horizontal directional drilling in underground coal mine, the paper contrastively introduces some treatment techniques, especially analyses the washover technology and then guides the design of the fishing tools applied to it. Eventually the washover technology and the fishing tools applied are proved to be practicable through the field trial.

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Keywords: horizontal directional hole; borehole accident; washover technology

The complete sets of horizontal directional drilling equipment and technology have been widely used presently in underground coal mine in most northern mining areas, such as Shanxi, Ningxia, Inner Mongolia and Shaanxi. This technology and equipment have the capacity to drill directional borehole with the deepest record 1110m and branch boreholes. Not only reduce the drilling efficiency, but also cause economic losses, the borehole accidents would happen inevitably when directional drilling is being taken as the coal seam geological conditions in our nation are complex. In order to dispose the borehole accidents efficiently and scientifically, the research of the fishing technology and the development of the fishing tools are set about actively, and we have already made some achievements.

1. Analysis on borehole accident

A lot of fuzziness, randomness and uncertainty exist in the practice of horizontal directional drilling in underground coal mine as it is a covert project with high risk [1]. The objects of directional drilling are stratified rocks (sometimes especially refer to the coal seam), the spatial position of the borehole is

* Corresponding author. Tel: 0086-29-81778190
Email address: mohaitao@cctegxian.com

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horizontal, and the aim of directional drilling is to control the borehole in accordance with designing to drill towards the target with the purpose of gas drainage, water detection and drainage, geologic structure detection and other directional construction. In the process of directional drilling, some complex conditions that would reduce the drilling efficiency and even cause serious borehole accidents that make negative impact on gas drainage and coal mining could happen because of unclear understanding of the coal seam and its top tray and bottom plate, or of the directional drilling technique itself, or of wrong determinations made by the operator. It is necessary for us who want to enhance drilling efficiency and reduce the cost to take correct understanding and disposal of the complex borehole conditions, and to try not to make improper decisions \cite{2}.

There is much possibility of borehole accidents in the practice of horizontal directional drilling in underground coal mine, the reasons for the borehole accidents making great damage to the construction are of wide varieties. According to the causes and characteristics of the borehole accidents in underground coal mine, we can divide them into three main kinds: drill pipe frozen, drilling pipe accident and drilling bit accident.

1.1. Drill pipe frozen

The main characteristic of a drill pipe frozen accident is that the whole set of drilling tools lose the freedom of reciprocating motion and rotation \cite{1}. Drill pipe frozen accident may happen at any time during drilling process, especially when we stop the washing fluid. The key factor to choose an applicable treatment for a drill pipe frozen accident is to confirm the right stuck interval. Three main drill pipe frozen accidents to be frequently encountered during horizontal directional drilling in underground coal mine are pointed out as follows.

- Hole sloughing sticking. Destabilization that may cause hole sloughing could happen by washing action in crumbly coal seam. The hole sloughing sticking would be very serious as the coal seam stress relief caused by a great deal of gas inrushing into the borehole.
- Borehole-shrinkage sticking. The borehole-shrinkage sticking would happen when we drill into the water-sensitive formation, and we can take timely treatment to deal with it. But when it happens during the drilling pause, it will be serious.
- Sediment arch sticking. Sometimes the cuttings size is big, and when they are carried to the bottom of the curved portion or the washing fluid circulating velocity comes down, the coarse wastes will pile up together gradually to come into being a sediment arch because the action of gravity makes a negative impact on the cuttings circulating out.

1.2. Drill pipe accident

There are two main kinds of drill pipe accidents, one is the drill pipe breaking or deformation, the other one is thread slipping or thread off. Both of them can cause borehole accidents that are difficult to dispose, and especially harder when the drill pipe is lost in the borehole.

1.3. Drill bit accident

The main kind of drill bit accidents is bit breakaway or bit tooth breakaway. The lost bit can be fished out or we can have a bit change to drill a branch borehole at an appropriate point. Bit tooth breakaway makes a negative impact on drilling efficiency and it also can cause drill pipe frozen accidents.

2. Analysis on fishing techniques
The key point of a successful fishing operation is to detect the accident timely, to decide the accident interval accurately, and to choose a fishing operation practicably. We can make an appropriate fishing operation from the makeup of string of the horizontal directional drilling in underground coal mine.

A set of drilling assembly in horizontal directional drilling developed by Xi’an Branch of CCTEG consists of inner-cable water swivel, inner-cable drill pipe, measuring probe, non-magnetic drill pipe, PDM and drill bit. The sketch map of the drilling assembly is shown as Fig. 1.

Fig.1. The sketch map of MWD drilling assembly

The outer diameter of the inner cable drill pipe and non-magnetic drill pipe is same while the bend angle of the PDM is 1.25°. There is much possibility for borehole accidents between the bend angle and drill bit as the drill pipe will bend with hole bending during horizontal directional drilling, and the non-magnetic sub is likely to break under outside load. The broken pipe will stay at the stuck point because of the gravity.

Comprehensively analyze the borehole accidents mentioned above and draw lessons from great quantities of practice in petroleum drilling, we can confirm three kinds of fishing techniques: washover, tap fishing and beche fishing.

2.1. Washover technology

Take advantage of the completeness of the stuck drill pipe in borehole, washover technology is widely used as treatment for drill pipe sticking accidents. This technique could break the chokepoint to open the stuck interval for fishing by rotary drilling without damaging the stuck pipe[3]. Washover technology is sketched as Fig 2.

Fig.2. The sketch map of washover technology

2.2. Tap fishing
Taper tap specially originates from petroleum drilling and this technology does have high efficiency on fishing out the stuck fish with coupling face such as oil tube and drill pipe by making thread on the inner bore.

When we take the tap fishing operation in horizontal borehole in underground coal mine, we should carefully both protect the fishing thread and guarantee the water passage unplugged in consideration of the action of gravity, and even should pay more attention on the tripping velocity and operate carefully on thread making.

2.3. Beche fishing

Beche fishing similitudes with tap fishing while beche fishing should make thread on the external of the stuck pipe and then pull out the pipe or take backoff operation to fish parts of the stuck pipe. The operating requirements of beche fishing technology are same as tap fishing when used in underground coal mine.

2.4. Contrastive analysis on fishing techniques

From the analysis above we can see that the washover technology is suit for a complete set of stuck drill pipe fishing with the understandable fundamentals and simple operation to protect the stuck pipe in high limit. But we should pay more attention to the washover parameters to ensure the operation safe as the risk still exists in rotary drilling in the collapsed coal seam.

Taper tap and beche are suit for fishing parts of the drill pipe broken or stuck in down hole with understandable fundamentals. But the fishing needs to be operated carefully and prudently on stabbing and thread making.

3. Fishing tools design

3.1. Washover fishing tools assembly design

From the fundamentals of washover technology we can know that the washover fishing tools assembly design should be complied with the rules as follows:

- Control the washover interspace properly. Taking comprehensive consideration of the requirement of washing fluid and safety of washover operation, we should give a proper design of the interspace between the extine of the stuck pipe and the in-wall of the washover pipe.
- To decrease the pipe wear, make sure that the in-wall of the washover pipe is glossy as well as the bit inner gauge protection and inner exposure are absent.
- To deepen the fluid-way of the washover bit properly to broaden the flow surface.

The structure size of the drillsteel set for horizontal directional drilling mainly consists of four aspects: the external diameter of a drill pipe is \( \Phi 73 \text{mm} \), partly \( \Phi 75 \text{mm} \); the length of a drill pipe is 3m; the structure angle of the PDM is 1.25°; and the external diameter of the drill bit is \( \Phi 96 \text{mm} \). Considering of the drill rig power and some relevant parameters, we finally decide that the external diameter of the washover pipe is \( \Phi 95 \text{mm} \) as well as the minimal internal diameter is \( \Phi 80 \text{mm} \), the length of a washover pipe is 3m (the structure drawing is Fig.3 a), and the external diameter of the washover bit is \( \Phi 105 \text{mm} \) with glossy in-wall and no edge angle so as to decrease the pipe wear (the picture is Fig.3 b).
3.2. Tap fishing and beche fishing design

Only one or two adapter subs and a centralizer if necessary are needed in tap fishing and beche fishing operation while the fishing pipe is just the ordinary drilling pipe. The size of the stuck pipe and the sticking loading are the main factors for the selection of taper tap and beche which can be performed with the standard “fishing tap and beche” (SY/T5114-2008) used in petroleum and natural gas drilling[4].

4. Fishing application

4.1. Washover technology used in Chengzhuang coal mine

The coal seam of No.4311 coal face located in the fourth mining area in Chengzhuang coal mine of Jincheng Coal Mine Group is high grade anthracite with metallic luster, the average coal seam thickness is 6.8m, and the average hardness index is less than one because of the soft coal bed. The coal seam of this coal face is yolk coal with high concentration gas, and the long boreholes for gas drainage that are constructed modularly by horizontal directional drilling are designed 500m to 600m deep and Φ96mm opening.

The construction of directional drilling was very difficult because of the soft and fragmented coal seam. The borehole accident indicated to come at 180m deep during the sixth borehole drilling, and then unfortunately the drill bit was stuck at 174m deep as well as the washing fluid pressure reached 8 to 10MPa although the operator tried to pull out the drill pipe promptly. Then washover fishing operation was launched immediately.

Screwed off the stuck pipe at orifice and blocked up the inner bore before washover operation to make sure that the washing fluid only entered from the interspace between the extine of the stuck pipe and the in-wall of the washover pipe to improve the efficiency of the washing fluid. The cuttings were carried out by the washing fluid through the interspace between the extine of the washover pipe and the in-wall of the borehole.

After being ready for washover fishing operation, the field operation was comparatively successful. The washover fishing parameters are shown in Table 1.

From the data above listed we can see that the directional drilling in the forepart of the borehole was normal and the stuck interval was between 156m~162m deep more or less, the drill pipe was stuck and the washing fluid pressure stepped up just because of the barrage caused by hole sloughing. The washover fishing operation broke the chokepoint to open the stuck interval for fishing successfully.
### Table 1. Data of washover fishing operation

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Washing fluid</th>
<th>Standby pressure (MPa)</th>
<th>Washover pressure (MPa)</th>
<th>Flow rate (L/min)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0~18</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
<td>250</td>
<td>Normal</td>
</tr>
<tr>
<td>18~144</td>
<td>1.4~1.5</td>
<td>1.5~1.8</td>
<td>250~230</td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>144~156</td>
<td>1.7</td>
<td>1.9</td>
<td>230</td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>156~162</td>
<td>2.0</td>
<td>2.3</td>
<td>230</td>
<td>Drill slowly with a great quantity of cuttings</td>
<td></td>
</tr>
<tr>
<td>162~173</td>
<td>1.9</td>
<td>2.1</td>
<td>230</td>
<td>Normal, pulled out the whole drill pipe, washover fishing operated successfully.</td>
<td></td>
</tr>
</tbody>
</table>

### 4.2. Tap fishing used in Rujigou coal mine

The 3215 coal face in Rujigou coal mine is the main continuous productive coal face of which the average coal seam thickness is 8.85m and the average hardness index is three. The existence of soft gray-black mudstone band with beddings has great restrictions on directional drilling.

495m drill pipes were stuck in the borehole during the directional drilling construction for 2# borehole in 1# drilling site because of the hole sloughing. A set of pipe string consisting of drill bit, PDM, lower non-magnetic drill pipe and half a sub were lost in the borehole although the operator tried to pull out parts of the pipes with slowly rotation. The schematic drawing of the lost pipe string is shown in Fig.4. Finally the tap fishing technology was selected to be the best treatment according to the analysis on the characteristics of the accident and the judgment that the breaking point was between 448m~490m deep resulted from the fluctuation of the pulling pressure.

![Fig.4 The schematic drawing of the lost pipe string](image)

Type GZ70x40-NC26 taper tap was selected to meet the fishing in considering that the inner diameter of the parted non-magnetic sub was $\Phi52$mm and the outer diameter of the lost pipe was $\Phi73$mm. Ran back into the borehole with taper tap slowly while circulating the washing fluid to ensure safety, and as the taper tap reached to 462.8m deep, it came to meet the top of the parted non-magnetic sub. Then the operator made up stab carefully and made thread successfully and finally fished out the lost pipe.

### 5. Conclusions

The borehole accidents during horizontal directional drilling in underground coal mine can hardly be avoided, but we can find appropriate treatments to solve them according to the analysis of the accidents. Based on the analysis of borehole accidents happened during horizontal directional drilling in underground coal mine and the selections of the treatment techniques as well as the successful application in Chengzhuang and Rujigou coal mines, we can conclude that:
Different fishing technologies with different characteristics are applicable to a certain scope. Washover technology is feasible with its special advantage to fish the stuck pipe while taper tap and beche fishing operation is difficult that requires highly to the operator because the hole is bent and the drill pipe is glued to the bottom of the hole as gravity taking effect.

The set of washover fishing tools guided from the washover technology are reasonable and practicable. One of the important factors to fish successfully is to act quickly as the accident happened. We should prepare fishing tools on the drilling scene to meet the requirement just in case.

Acknowledgements

Thanks for the National science and technology support project “Development for horizontal long borehole drill equipment and drill technology in underground”.

References