Engineering solutions for casing drilling in pre-mine drainage

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Abstract. The authors discuss application of the casing while drilling technology in pre-mine drainage. The currentness of this technology and its advantages are proved. The scope of the discussion embraces operating principle of the equipment used in casing drilling. A new method for batch removal of drill fines from large-diameter boreholes is described. The economic efficiency of the technology is evaluated in terms of drainage holes drilled using rig SANDVIK DE-880 in Kirov mine at SUEK-Kuzass.

1. Introduction

Drilling and casing in difficult ground conditions is a challenge both to mining industry and civil construction. Instable rocks constitute risk of sloughing in wells and, as a consequence, impractibility of casing [1, 2]. Furthermore, drilling equipment can be lost in wells and never pulled out [3, 4].

The casing drilling systems are intended for drilling wells and holes in difficult ground conditions (boulder beds and cobble deposits, water inflows, etc). Systems of pneumatic percussion drilling are expedient to be used in casing drilling in ground conditions favorable for DTH hammers [5, 6].

To this effect, a DTH hammer is equipped with a special rock-breaking tool of original design which allows drilling diameter larger than casing diameter. During drilling, a casing pipe goes down the hole by gravity (Figure 1a). Vibration of the rotary–percussive mechanism facilitates the casing pipe driving by reducing the force of friction at the rock–casing interface. After drilling is completed, dimensions of the rock-breaking tool can be diminished to the internal diameter of the casing, and the tool is freely pulled out of the well (Figure 1b). If necessary, drilling can be continued using a standard cylindrical tool (Figure 1c) [7, 8].

![Figure 1. Operation of the hammer drill bit: (a) casing drilling; (b) removal from the well; (c) drilling without casing.](image-url)
2. Casing drilling for methane drainage

According to safety regulations for gas outburst-hazardous coal mining, the mines use the method of pre-mine drainage with holes drilled from ground surface to a coal seam. SUEK-Kuzbass mines practice the method of rotary drilling SANDVIK DE-880 multi-purpose drill rig. First a well is drilled, then different diameter casing is installed with cementing of annular space.

According to specifications of drainage hole drilling from ground surface to longwall no. 24-60 in Boldyrevsky coal seam in Kirov Mine, design of the casing string has the parameters as shown in Figure 2a. Hole drilling is followed by different diameter casing and cementing of annular space.

![Figure 2. Well design: (a) according to drilling specifications for Kirov Mine; (b) casing drilling technology.](image)

The drilling process has four stages in conformity with the number of casing pipes. The telescopic step-wise design of a well is governed by the risk of wedging of a pipe during its installation after the drilling tool is pulled out. As a rule, the length of each step is determined based on the exploration data, and transition to smaller diameter drilling is undertaken in the zone of change in properties of rocks.

Application of the casing drilling technology in this specific case will allow considerable reduction in the time of drilling and casing operations, cost saving due to elimination of two connecting pipes (Figure 2b) as well as abridgement of upward/downward operations and cementing volume.

**Table 1. Durations of drilling and volumes of drilled solids.**

| Hole depth, m | Casing pipe diameter, mm | Hole diameter, mm | Volume of drilled solids, m³ | Drilling capacity, m/shift* | Drilling duration, shift* |
|---------------|---------------------------|-------------------|-----------------------------|-----------------------------|--------------------------|
| 25            | 426                       | 490               | 4.71                        | 5–15                        | 1.67–5                   |
| 55            | 325                       | 393.7             | 3.65                        | 8–20                        | 1.5–3.75                 |
| 225           | 273                       | 304.5             | 12.37                       | 10–25                       | 6.8–17                   |
| 285           | 219                       | 244.5             | 2.82                        | 20–40                       | 1.5–3                    |
| **Total: 23.55** |                           |                   |                             |                             | **Total: 11.47–28.75**   |
| 55            | 325                       | 348               | 5.23                        | 9–22                        | 2.5–6.11                 |
| 285           | 219                       | 240               | 10.40                       | 21–41                       | 5.61–10.95               |
| **Total: 15.63** |                           |                   |                             |                             | **Total: 8.11–17.06**    |

*Work shift is 12 h.
In order to evaluate economic efficiency, let us compare durations of drilling and volumes of
drilled solids in drainage hole design using the casing while drilling technology and in drilling with
subsequent casing (Table 1).

It is seen from Table 1 that the casing drilling technology shortens the period of drilling by
30–40% and reduces the volume of drilled solids by 34%. The fact that the two-step hole drilling
needs drilling equipment of two rather than four standard sizes speaks in favor of the efficiency of
the proposed approach.

Casing drilling in subsurface soils and weak rocks can go without drilling machines. The casing
pipe is driven in soil by pneumatic hammers in this case [9]. Vibropercussion drilling technique can
drive pipes with a diameter from 102 to 3600 mm to a depth to 120 m. Material of pipes is limited to
steel as a rule, due to considerable forces transferred to the pipe while driven. This method is
applicable in a wide range of rocks—from sand, silt and plastic clay to weathered rocks, chalky clay and
schist [10].

When a pipe is subjected to dynamic driving, rocks enter inside the pipe, compact gradually and
form a plug. As a consequence, new portions of rocks cannot enter the pipe and are pressed in the hole
walls, which intensifies radial deformation in surrounding rock mass, and the pipe is penetrated in
rocks at a much lesser rate down to complete cessation of the process [11, 12]. Thus, timely removal
of soil plugs from pipes is an important factor governing efficiency of the whole technology [13].

In the conditions of vertical pipe driving, it seems logic and wise to remove soil plug from the
pipe by batches without auxiliary equipment. The implementation of such technology in pipe driving
using pneumatic hammer is depicted schematically in Figure 3 [14].

![Figure 3. Pipe driving with removal of soil plug by batches: 1—driven pipe; 2—air line; 3—air gap; 4—soil; 5—compressed air supply hole; 6—adapter with discharge hole; 7—tightening device; 8—air supply hose; 9—compressor; 10—air hammer; 11—lift crane.](image)

In this manner, compressed air is supplied to bottom hole end of the pipe 1 via a separate line 2.
As soon as a soil plug 4 is formed, compressed air is fed under pressure inside the pipe through the hole
5. The air cuts a batch from the plug, generates an air gap 3 and displaces the soil batch upward the
pipe 1 to be ejected to the pit through the discharge hole of the adapter 6. This sequence of operations
is repeated in the course of the soil plug formation until the project depth of the pipe penetration is
reached. Soil batches can be removed from the free end of the pipe but this needs the air hammer to be
disassembled.
The whole process of batch-wise removal of soil plug can be divided into three stages: formation of a soil batch, separation of the soil batch from the plug and displacement of the batch along the pipe up to removal. It is important that the soil batch is compact in the zone of cutting and fills the whole cross-section of the pipe. This is required to create and maintain compressed air pressure sufficient to cut and displace the soil batch to be then removed. At the same time, it is clear that the plug is over-compact, it can be impossible to cut a batch, or in case of loose soil, an air pocket can be formed, which will result in the pressure drop in the yielding medium. A signal of the plug formation and removal is a drop in the penetration rate. The other factors influencing cutting and removal of soil plugs is vibration of the pipe in adjacent rock mass and elastic deformations of the pipe walls under impacts, which can lower the drag force by 30–90% \[12, 15\].

Replacement of the large-diameter drilling with subsequent casing in weak rocks by impact driving eliminates the risk of loss of drilling equipment or wedging of the casing pipe due to damage or erosion of hole walls. Furthermore, impact driving in the starting interval of a vertical hole excludes expenditures connected with the larger diameter drilling tools and operating costs of drilling rigs at this stage.

3. Conclusions
The application of the casing drilling technology in drainage hole drilling from ground surface will reduction of drilling and saving of drilling cost due to increased productivity of the process and shortened period of upward/downward operations. The methods proposed in this paper will make it possible to avoid accidents connected with the hole wall sloughing and, as consequence, wedging of casing pipes in holes.

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