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THERMAL SPALLATION DRILLING TECHNOLOGIES

Summary. Some drilling methods described in this publication are still subject to research. This documents an ongoing effort to develop new drilling techniques, meeting requirements for fast and efficient drilling, at the lowest possible cost and in the shortest possible time.

TECHNIKI WIERTNICZE OPARTE NA SPALACJI TERMICZNEJ

Streszczenie. Przedstawiono techniki wiertnicze będące wciąż w stadium badawczym. Artykuł dokumentuje wysiłki w kierunku rozwijania nowych technik wiertniczych, spełniających warunki wydajnego wiercenia przy minimalnych kosztach i w najkrótszym możliwym czasie.

1. Introduction

Risk breaking and disintegration mechanisms can be divided into 4 basic groups: mechanical induced stress, thermally induced stress, melting and vaporization, and chemical reaction drilling. Principles of thermal stress drilling are described later in the text.

Basically, there are two ways of thermal attack on rock :

a) by heating it up to 400 - 600 °C and cooling it down, which would cause thermal stress and rock disintegration;

b) by heating it up to 1 000 - 2000 °C thus creating conditions for melting or vaporization of rock.

The latter method is more variable as it can be used for both thermal cracking and degradation of rock by distribution of the supplied energy across larger area in order to avoid melting. This method, however, has limited use only to low-diameter bores due to its high power requirements. It can be efficiently used for disintegration of hard rock with sheet structure [2].

2. Flame drilling

Flame drilling works in conditions between thermal stress and melting/vaporization of rock. Fuel and oxygen are fed to combustion chamber at the bottom of well through pipes inside the conventionally rotating drilling pipe (figure 1). The flame which is about 2400 °C hot flashes from the nozzles to the bottom of well at app. 1 800 m.s^{-1}. Water supplied through the third pipe is cooling down the combustion chamber, the nozzles and the burnt bore. Operational characteristics of the drilling are listed in table 1. The tool also includes a mechanical reamer for calibrating of the hole and removal of disintegrated rock [1], [2].

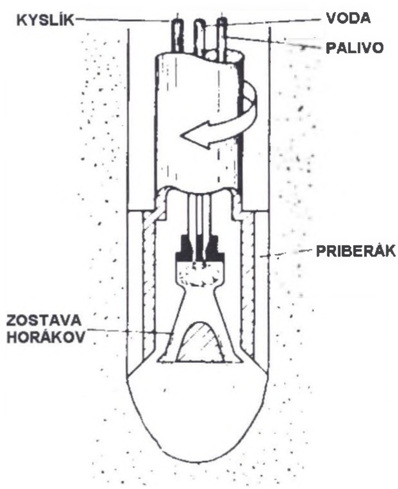

Fig. 1. Flame drilling
Rys. 1. Wiercenie płomieniowe

Tests have shown that the maximum drilling progressive speed v_p was reached when more »rich« oil-oxygen mixture was used (0,33 - 0,36). The specific volumetric energy for this rock disintegration method is from 3 000 to 1 000 MJ.m^{-3}, which is from 2 to 7-times more than 1500 MJ.m^{-3} required to heat-up the rock to 400 - 600 °C.

Considerable portion of energy is consumed for heating-up of walls, thermal and kinetic energy of gases escaping from the well. Only smaller portion of energy is transferred to the well face, especially due to short contact time of high-speed gases and the rock. Flame cutting uses relatively cheap energy source. It can be used where fast rock heating is required.

Table 1

Flame cutting operational characteristics

Bore diameter D_V (mm)	160 - 320
Drilling progressive speed v_p (m.hour-^{1})	3 - 12
Oxygen consumption m_{KYS} (l; kg.cm^{-2})	28 000; 10,5
Oil consumption m_{OL}(kg.cm^{-2})	7
Oil/water ration	0,355 kg.1kg
Water consumption m_{VOD}(kg.cm^{-2})	4,2
Flame temperature t_{pl} (°C)	2 400
Flame speed v_{pl} (m.s^{-1})	1 800
Power P (kW)	373 - 746

3. Enhanced flame drilling

Drilling technique and the toll itself are basically identical to the above-described tool. The difference is that instead of oxygen, nitric acid is used as an oxidizing agent. This results in faster reaction, higher power and app. four-times higher progressive speed (table 2).

Table 2

Comparison of flame drilling and enhanced flame drilling [2]

	Flame	Enhanced flame
Bore diameter D_V (mm)	180	280
Progressive speed v_p (m.hour-^{1})	5	18
Specific energy w (MJ.m^{-3})	23 000	16 700
Combustion chamber pressure p_{SK} (MPa)	0,5-0,7	3
Fuel consumption m_{PAL} (g.s^{-1})	37	140
Fuel consumption m_{PAL} (l.hour-^{1})	140	530
Oxygen consumption m_{VZD} (g.s^{-1})	103	-
Acid consumption m_{KYS} (g.s^{-1})	-	610
Water consumption m_{VOD} (g.s^{-1})	900	950

The author Shapir used enhanced flame drilling with the fuel ratio (oil/nitric acid) 1: 4,15. The specific volumetric energy *w* of this enhanced flame drilling was lower by 30% which indicates that the nitric acid flame transfers the heat to rock more efficiently than the oxygen one. It is probably caused by the flame temperature.

Table 3

Progress speed of enhanced flame drilling of silica iron

Bore no.	Well length l (m)	Maximum drilling speed v_{max} (m.hour^{-1})	Average drilling speed v_{pr} (m.hour^{-1})	Bore diameter D_v (mm)	Specific volumetric energy w (MJ.m^{-3})
1	12,0	18,0	18,0	280	15 500
2	16,0	20,0	12,5	330	15 900
3	11,5	18,0	18,0	270	16 300
4	14,5	19,0	15,0	280	16 300
5	16,5	24,5	21,5	285	16 300
6	16,0	20,0	16,0	285	16 600
7	14,0	25,0	9,3	350	19 700
8	2,0	6,5	6,5	180	117 000

Total power transferred to rock was 447 kW [2]. The data from enhanced flame drilling in silica iron are described in table 3. Using of drill liquid will decrease the maximum progress speed v_p from18 - 25 m.hour^{-1} (well diameter 27 - 35 cm) to 6,5 m.hour^{-1} [1], [2].

This means that flame cutting is not suitable if the well is filled with drill liquid. Individual tests showed that the enhanced flame drilling technique is more efficient than flame drilling. Drilling speed is the key factor why this tool is so interesting, despite higher price of nitric acid..

4. Terra-Jetter drilling (Terra Jet drilling)

This drilling technique is using cyclic changes of rock temperature to create thermal stresses and degradation of the rock (figure 3). In the first stage, superheated steam with the temperature of 250 - 500 °C and the pressure 4 - 6 Mpa will heat-up the rock to approximately 300°C in 3 minutes. In the second stage liquid nitrogen (-196 °C) cools down the heated rock; this temperature shock crushes and disperses the rock. This heating-cooling cycle repeats. In stage three, a low-pressure steam (1 - 1,8 MPa) removes the crushed rock from the bottom of well and preheats it again. Progressive speed of these tools in semi-hard rock is ca. 10 m·hour^{-1} (18 cm·min^{-1}); in the hardest rock it is 3 - 6 m.hour-^{1} (5 - 10 cm·min^{-1}).

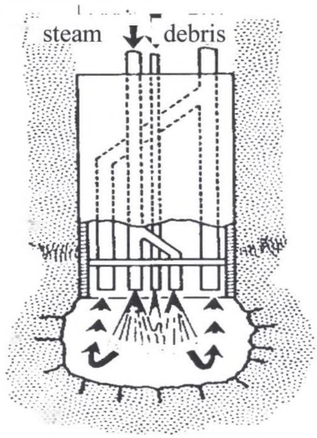

Fig. 3. Terra-Jetter drilling [1, 2]
Rys. 3. Wiercenie urządzeniem Terra-Jetter [1, 2]

5. Conclusion

Some drilling methods described in this publication are still subject to research. This documents an ongoing effort to develop new drilling techniques, meeting requirements for fast and efficient drilling, at the lowest possible cost and in the shortest possible time.

The technique often used abroad is the Water Jet. It is mainly thanks to its economical benefits as it avoids such often replacement of worn-down bits, which are fairly an important cost factor in the drilling process. It is adapted to the latest boring technologies, in order to fulfil the high requirements. Despite many advantages to the classic rotation drilling, it is still under research for further development.

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