E3S Web of Conferences **105**, 01052 (2019) https://doi.org/10.1051/e3sconf/201910501052
IV th International Innovative Mining Symposium

New Innovating Processes of Rock Disintegration

Gabriel Wittenberger[1,*], Erika Škvareková[1] and Martin Ocilka[1]

9. **Institute of Earth´s resources, Department of Montaneous Sciences, Technical University of Košice, 040 01, Slovak republic**

Abstract. Over the past years, deep drilling technology developed quickly. New technologies better quality of drilling work and accelerated the drilling process. At present, 20-25% are new techniques while 75-80% drilling methods used worldwide are traditional. Slovakia is quite at the rear of this tendency: our utilization ration shows 95-98% traditional drilling methods, in comparison to only 2-5% new ones. Advancement of new deep well boring technologies causes the evolution of new types of drilling sets for deep drilling (depending on applied techniques). Techniques used have a mechanical and physical impact for drilling of rock. Several tests and analyses of disintegration and drilling methods were performed over the last years. The article focuses on a description of the working principle and utilization possibilities.

1 Introduction

The introduction of rotary drilling, however, was only the beginning of a long series of successful innovations and the progress made during the 20th century in the drilling of oil wells. Some of the most important innovations have helped to increase the efficiency of oil production while also enabling the search for oil deposits. Market characteristics should guarantee work discipline during technological procedures and wise utilization of equipment from both economic and technical points of view Effectiveness of drilling process depends on the selection of technology and drilling techniques. At the present drilling technology restricts the time for drilling itself as quite a lot of time is absorbed by extra operations. In addition, it is necessary not only to stop the rotation of the drill string but also the circulation of the mud [1,4]. Because of physical and chemical impact on rock, the new technologies are reaching good drilling results at higher progressive speeds and a shorter time than the conventional rotation drilling. The mentioned advantages of the physical-chemical drilling methods-though still partly under research-are promising for the near future [3].

[/] Corresponding author: gabriel.wittenberger@tuke.sk

2 Materials and Methods

2.1 The thermal stress drilling

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

[1] by heating it up to 400 - 600 C and cooling it down, which would cause thermal stress and rock disintegration;

[2] 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 a distribution of the supplied energy across a 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 [5,6].

2.2 Flame drilling

Flame drilling works in conditions between thermal stress and melting/vaporization of rock. Fuel and oxygen are fed to the 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 [6 .

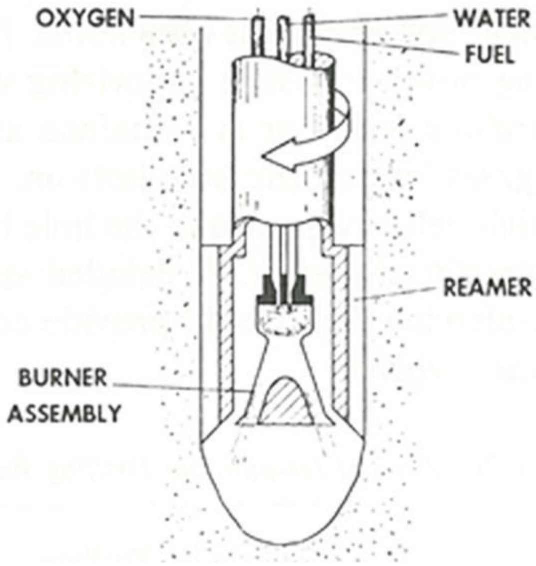

Fig. 1 Flame drilling [6 .

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 [5 . 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 [6 .

Table 1. Flame cutting operational characteristics [6 .

Bore diameter DV (mm)	160 - 320
Drilling progressive speed vp (m.hour-1)	3-12
Oxygen consumption mKYS (l; kg.cm-2)	28 000; 10,5
Oil consumption mOL (kg.cm-2)	7
Oil/water ration	0.355 kg.1kg
Water consumption mVOD (kg.cm-2)	4.2
Flame temperature tpl (C)	2 400
Flame speed vpl (m.s-1)	1 800
Power P (kW)	373 - 746

A considerable portion of the energy is consumed for heating-up of walls, thermal and kinetic the energy of gases escaping from the well. The only smaller portion of the energy is transferred to the good face, especially due to short contact time of high-speed gases and the rock. Flame cutting uses a relatively cheap energy source. It can be used where fast rock heating is required [6 .

2.3 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 a faster reaction, higher power and app. four-times higher progressive speed (table 2).The author Shapir [7 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. Total power transferred to rock was 447 kW [5,6 .

Table 2. Comparison of flame drilling and enhanced flame drilling [6 .

	Flame	Enhanced flame
Bore diameter DV (mm)	180	280
Progressive speed vp (m.hour-1)	5	18
Specific energy w (MJ.m-3)	23 000	16 700
Combustion chamber pressure pSK (MPa)	0.5-0.7	3
	Flame	Enhanced flame
Fuel consumption mPAL (g.s-1)	37	140
Fuel consumption mPAL (l.hour-1)	140	530
Oxygen consumption mVZD (g.s-1)	103	-
Acid consumption mKYS (g.s-1)	-	610
Water consumption mVOD (g.s-1)	900	950

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}. This means that flame cutting is not suitable if the well is filled with drill liquid [5 .

Table 3. Progress speed of enhanced flame drilling of silica iron [5,6 .

Bore nr.	Well length L (m)	Maximum drilling speed vmax (m.hour-1)	Average drilling speed vpr (m.hour-1)	Bore diameter Dv (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

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 the higher price of nitric acid [6 .

2.4 Electrical current drilling

Electrical current drilling/rock disintegration principle is based on the idea to create thermal stresses which would degrade the rock and thus making conventional drilling easier (figure 2).

Most rocks are semi-conductive. Only metallic minerals/ores have higher conductivity (by several orders), depending on the content of metallic elements. Hence, this disintegration method is used mainly for this type of rocks [6,8 .

A current with the frequency 60 Hz is generated during drilling and transferred to the rock through a sharp bit. The bit rotates with low rpm and the air which circulates through the well is removing the rock fragments while attacking the rock with high temperature [1,6 . This creates thermal stresses which crush the rock. Research results are presented in table 4.

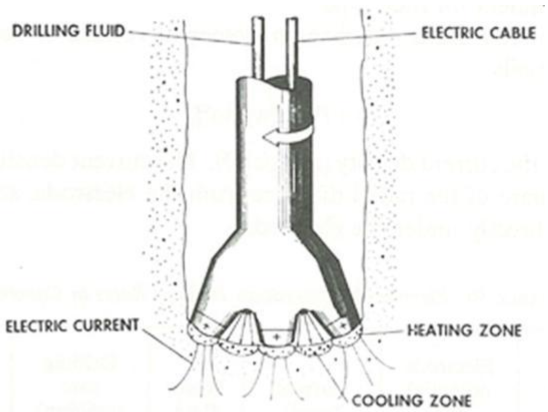

Fig. 2. Electrical current drilling [5, 7 .

Electrical power attacking the rock is expressed by the relation:

$$P \quad k \frac{U^2}{R} \quad [W \qquad (1)$$

where k – a constant specifying type of electrode (cm),
U – voltage on an electrode (V),
R – rock resistance ( ).

Total progressive speed depends on the type of drilled rock.

Power P transferred to the elementary volume of the rock under the bit can be expressed by the equation:

$$P \quad i^2 R \quad [W \qquad (2)$$

where i – current intensity (A).

Table 4. Electrical current drilling operational characteristics [5, 7 .

Bore diameter Dv (mm)	25-51
Voltage U (V)	600 - 1 000
Current I (A)	2-10
Current frequency fp (Hz)	60
Power P (kW)	1.2 - 11
Power coefficient kv (dim. free)	0.93 – 1.06
Circumferential speed a (rpm)	90
Bit axial pressure F(A)	110 - 120
Air consumption mVZD (l.min-1)	57
Progressive speed of drilling vp (cm.min-1)	8-64

Applicability of this method in the mining industry is proven by experience from the USA. In one iron-ore deposit, they registered an increase of driving speed from 0,025 to 0,6 m.hour-1 ; in other ore-deposit, it was the increase from 0,2 to 0,9 m.hour-^{1} (they used an autotransformer with the power 100 kWA resp. 60 kWA).

In addition to this, many tests were made during which the rock was preheated by electrical current to 816 C (with simultaneous use of a cutting-type bit). With this temperature, the rock lost practically all its strength [10 . Although the specific volumetric energy w is the same as for conventional rotation drilling, this method can be used for drilling of rock with very good conductivity (e.g. quartz) [6 .

3 Conclusion

Market characteristics should guarantee work discipline during technological procedures and wise utilization of equipment from both economic and technical points of view.Effectiveness of drilling process depends on the selection of technology and drilling techniques.At the present drilling technology restricts the time for drilling itself as quite a lot of time is absorbed by extra operations. In addition, it is necessary not only to stop the rotation of the drill string but also circulation of the mud [10,11 .

Because of physical and chemical impact on rock, the new technologies are reaching good drilling results at higher progressive speeds and at a shorter time than the conventional rotation drilling. The mentioned advantages of the physical-chemical drilling methods-though still partly under research-are promising for the near future.

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