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OIL AND GAS EXPLORATION

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NEW DEEP - WELL BORING TECHNOLOGIES OF ROCK DISINTEGRATION

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ABSTRACT

Over the last decades, deep drilling technology expanded fast. Newly created progressive technologies improved quality of drilling work and speeded-up the drilling process. Currently, 75-80 % drilling methods used world-wide are traditional, while 20-25 % are new techniques. Slovakia is a little behind this trend: our utilization ration shows 95-98 % traditional drilling methods, compared to only 2-5 % new ones. Together with development of new deep-well boring technologies, new types of drilling sets for deep drilling are developed and modified (depending on applied techniques).These techniques use both mechanical and physical impact for drilling/crushing of rock. Many tests and analyses of these drilling/disintegration methods were carried out in the past. Here, we will concentrate on description of the work principle and utilization possibilities. Rapid growth in demand for energy and its consumption will be increasing farthest in spite of necessary economical measures, economical restructuring, and more effective use and other measures. It is primarily conditioned by raising growth of the world occupancy, process of the world industrialization and raising the living standards all over the world.

Keywords: deep hole drilling, rock disintegration, explosive, erosion drilling, drilling tools

INTRODUCTION

Market conditions should naturally guarantee work discipline during technological procedures and rational utilization of equipment from both technical and economical points of view. Efficiency of drilling process therefore depends on selection of drilling techniques and technology. Current drilling technology limits the time for drilling itself as a lot of time is »consumed« by auxiliary operations. These are usually tiring and dangerous operations with drilling equipment. In addition, it is necessary not only to stop rotation of the drill string but also circulation of the mud [1], [2], [3].

Through physical and chemical impact on rock, the new technologies are achieving good drilling results at higher progressive speeds and at 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 [4], [5].

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EXPLOSIVE DISINTEGRATION

One of the first tools used for explosive disintegration is McCullough's tool. Its principle is simple. Specially shaped blasting charge is lowered-down to the well suspended on rope, as it hit the bottom it detonates. Then the tool must be pulled up and the well shaped mechanically before another charge can be put inside. This tool is used in special cases, e.g. for disintegration of stock bits, parts of casing or for drilling in very hard formations. Russian design was based on sending down special capsules

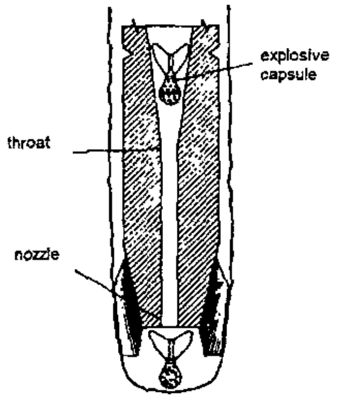

Figure 1 Russian model of explosive drilling [5].

Pipe end is narrowed several dozens of centimetres above the well bottom. The capsule is basically a ball with side wings, divided by a membrane separating two liquids (Figure 2). As the capsule passes through the narrow section, the membrane breaks and the liquids inside create explosive mixture. Subsequently the wings are pulled-off. This will release the pin which hits the detonating fuse and ignites it when the capsule bumps into the rock.

Table 1 Explosive capsule drilling operating characteristics [6].

Cartridge weight m_a (g)	50
Energy W_K (kJ.capsule^{-1})	250
Explosion speed v_e (capsules.min^{-1})	3 - 12
Penetration h_e (mm.explosion^{-1})	5 - 20
Length of bore l (m)	100 - 200
Bore diameter D_v(mm)	200 - 400
Average bore diameter D_P (mm)	340
Power P (kW)	12,7 - 49

During tests with this tool, 50 g charges were used, lowered-down with the frequency 12 pieces per minute (Table 1). This generated the power 50 kW. This drilling model was used for drilling of deep wells (3 000-4 000 m). Progressive speed in siliceous lime stone was 4-times higher with this tool, compared to classic bits [6].

Distance of the tool from the well face shall be kept at 20 - 40 cm. Currently, a lot of effort is made to control this distance using a hydraulic jack or other means.

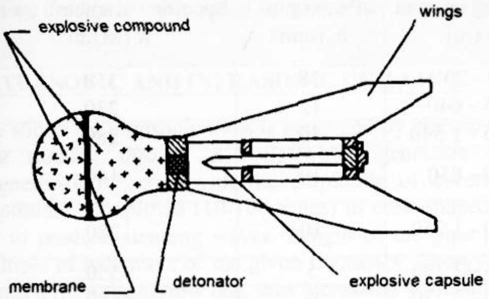

Figure 2 Russian explosive capsule [6].

Power P achieved by explosive drilling is calculated as following:

$$P = 0{,}000022 \cdot v_K \cdot z_K \cdot W \cdot 0{,}7457 \quad \text{(kW)} \quad (1)$$

Where:

V_k – capsule feeding speed (capsules.minute^{-1}),

Z_k - explosive capsule load (g.capsule^{-1}),

W - explosive energy (J.g^{-1}).

Table 2 shows that depth of well has no significant impact on progressive speed of drilling. Specific energy w for drilling of various-type rocks is within 140-390 MJ.m^{-3} (comparable to conventional drilling).

The least suitable rock for explosive drilling is clay because it forms a plastic paste which is difficult to remove from the well face.

Another method of releasing a stuck drilling tool is by using targeted explosive capsules. Especially suitable is the use of plastic explosives to shatter steel segments with gaps between individual parts (sheets) of bolted segments and such segments where, due to their significant thickness, a large explosive capsule would be needed whose placement would be difficult. When using plastic explosives the weight of the explosive, calculated according to formulas for shattering of steel segments, is reduced by one third. When placing the explosive between individual segments, the weight is calculated for the thicker part of the segment. If the explosive is placed between them directly on the segment, the thickness used in calculating the amount of explosive needed disregards the height of the bolt heads [7].

If a complete perforation of a steel segment or its complete severing is desired, the plastic explosive is used to create targeted explosive capsules, which significantly improves the effect when compared to a concentrated explosive. A further improvement of the effect can be achieved by placing a conical or half sphere-shaped tin insert inside the targeting cavity. Explosives have to stick to the segments to be shattered in the entirety of their area [8].

Table 2 Rock type and well depth effect on progressive speed of explosive drilling [6].

Rock	Drilling interval h (m)	Penetration h_p (mm)	Specific volumetric energy w ($MJ.m^{-3}$)
Lime stone	0 - 30	18	150
Lime stone	615 - 640	12	230
Lime stone	1 515 - 1 540	10	280
Lime stone and dolomite	790 - 850	19	140
Lime stone and dolomite	1 220 - 1 250	10	280
Lime stone and clay	2 235 - 2 290	5	550
Lime stone and clay	2 400 - 2 770	4	680

Progressive speed is partly reduced by fragments remaining in the well face, which are decreasing effect of the following explosions. Despite this fact, these capsules are very popular as they allow drilling in al types of rock at sufficiently high progressive speed and reasonable power. Their major disadvantage is high price (720 capsules.hour^{-1} at the given consumption during drilling) and inefficient boring of soft rock (such as clay). This led to attempts to modify the explosive drilling by use of chemical liquids. New drilling model based on this principle was designed by the Russian scientist Ostrovskij. Here, the explosive liquids are mixed directly in the well face in so-called detonating chamber (Figure 3) [4].

Different pressure of liquids is created by two vertical pistons. The piston injects the fuel into detonating chamber at the well face, where explosive mix is produced by adding oxidizing agent thus enabling explosion. Proper timing of individual components is controlled by shape and section of channels. This means that movement of liquid components stops until the generated explosive pressure drops to the required level. This procedure repeats in cycles. Explosion frequency at the well face is from within the range 150-2500 explosions.min^{-1}. As you can see, explosive chemical liquids are better than explosive capsules, not only in terms of power but also explosion frequency. Selection of chemicals and oxidizing agent depends on used drilling fluid [9].

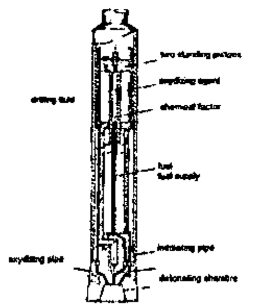

Figure 3 Explosive drilling by use of chemical liquid [6].

All tests carried out based on this drilling model indicated that drilling is suitable, however, this model s not used due to problematic cleaning of face of well using a drilling fluid (when remaining fragments are reducing power of some explosions) [9].

ULTRASONIC AND INFRASONIC DRILLING

The sound for ultrasonic tools is generated by electric current with the frequency 20-30 kHz running through a coil, which generates synchronous oscillation of its magnetostrictive core with the amplitude of several micrometers (Figure 5). The amplitude is amplified (10-100 times) in cone-shaped pipe of the length chosen so as not to produce standing waves. Length of the pipe plus the drilling tool is an exact multiple of half-wave of the given frequency. Energy is supplied to the wider end and released from the narrow one, thus increasing wave amplitude [6].

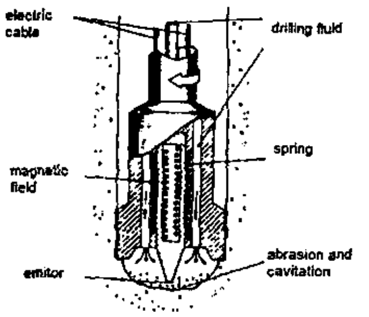

Figure 5 Ultrasonic drilling

There are two mechanisms for rock disintegration using the described tool:

(1) The sound creates cavitations in the liquid, energy transfer principle makes the micro bubbles proceed towards the rock and disintegrate it by implosion. The disadvantage, however, lies in the fact that the cavitations disappear at the pressure above 0,5 - 0,7 MPa so it's not usable for deeper wells.
(2) The principle applied here is an abrasive disintegration. Hard abrasive materials are put below the tool, making a suspension. Turbulence accelerates the particles, which are breaking and removing the rock.
In water environment, the emitter generates cavitations advancing to the rock where they collapse generating strong impulsive pressure microscopically crushing the rock.
Research of AV SNŠ shows major influence of abrasion, while cavitations are considered less important. Drilling progressive speed depends on type of used abrasive material (which can be seen in table 4). The ultrasonic drilling progressive speed increases with increasing grain size of the abrasive material and increasing vibration amplitude, as the maximum speed and moment of impact are equal to this amplitude.

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Progressive speed of such ultrasonic tools is 0,06 - 1,2 m.h^{-1} (0,1-2 cm.min^{-1}); water proved to be the most suitable environment for transfer of waves [6].

Table 4 Abrasive material type effect on ultrasonic drilling speed.

Type of abrasive	Drilling progressive sped v_p (cm.min^{-1})	
	Soda glass	Wolfram carbide
Boron carbide	2,0	0,082
Diamond	1,8	0,082
Silicone carbide	1,6	0,051
Aluminium	1,3	0,004
Sand	0,9	0,004

As the sound frequency is related to the bore diameter (the higher the diameter the lower the frequency) ultrasound can be used for drilling of wells to the max diameter ϕ 6,5 cm. Exceeding this value, the sound would reach audible range and could cause troubles to operators [2]. The specific energy *w* is from within the range 10 000-100 000 MJ.m^{-3}, depending on type of rock. These are generating an amplitude up to 5 cm at frequencies under 16 Hz,; this amplitude creates large impact forces targeted usually directly at conventional disintegration tools. This way the large impact forces are used optimally. Total power is only from 2 to 4 kW [4]. Due to low drilling progressive speed and low power, practical use is impossible, unless someone would come up with the method how to increase total efficiency of this technology.

CONCLUSION

Some drilling methods described in this article 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 [10].

The given examples are showing how time and money can be saved with increased drilling speed and overall safety. Geological research and surveying includes a wide range of researching, technical and economical activities [11]. The main task of geological surveying is determination of geological composition of the surveyed area, searching for deposits of minerals, finding new sources of underground mineral and thermal water, determining geological conditions of foundation beds, examining and redeveloping slide areas, examining conditions for potential construction of underground gas tanks/reservoirs and underground repositories of radioactive waste [12], [13], clarifying geological factors influencing the environment and solving technical and commercial issues [14].

Results of geological work is essential for today's and future exploitation of minerals, solving of water management problems, protection and utilization of underground, healing and table mineral waters, rational/efficient piling, soil quality classification, prospective use of geothermal energy and further clarification of economical factors influencing human health and the environment [15]. This wide spectrum of geological work requires use of new drilling technologies/techniques and equipment.

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