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DRILLING BITS IN PERCUSSIVE-ROTARY DRILLING TECHNOLOGY (DOWN THE HOLE DTH)**

1. INTRODUCTION

Drillbit is a tool used for drilling cylindrical holes in rocks by cutting, crushing, abrasing or grinding. Drillbits work the rock mass with their entire face. The core drill is a tool for drilling cores, or rings, leaving a drilling core of the rock. The percussive-rotary drilling is now more commonly applied, mainly in hydrogeology and geoenergy [1].

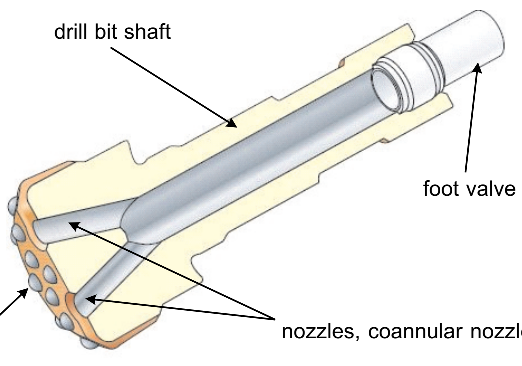

Fig. 1. Block diagram of drillbit for DTH drilling [2]

Drillbits for down-the-hole (DTH) applications constitute an important element of percussive-rotary drilling. They have a rather simple design (Fig. 1) and consist of such elements as: foot valve, drillbit shaft and face with sintered carbide inserts responsible for rock

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drilling operations. Other important elements are nozzles (air outlets), with which pressurized air is jetted out, purifying the borehole from the cuttings. Therefore it is very important to properly select the drillbit, depending on such factors as: depth of the planned borehole, its diameter, purpose and type of the drilled rocks.

2. SINTERED CARBIDE INSERTS

Each drillbit for DTH applications is equipped with sintered carbide inserts. Their shape may differ, depending on the geological conditions of the drilled rock layers. The classification of sintered carbide inserts has been presented in Figure 2.

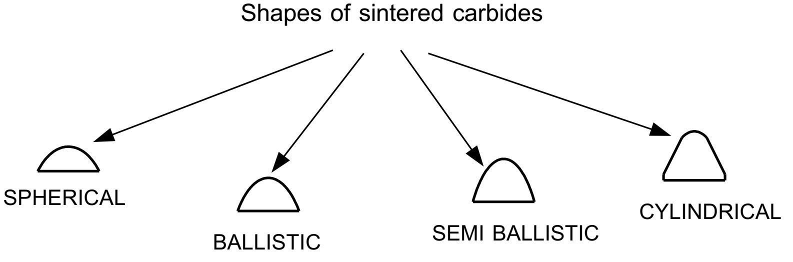

Fig. 2. Shapes of sintered carbide inserts [2]

The shape of sintered carbide inserts depends on the hardness of the drilled rocks. Cylindrical inserts are used for soft rocks making the drilling operation quick and efficient. Otherwise, rounded-shape inserts are applied. The drilling time with such drillbits is longer. Besides ballistic and semi ballistic sintered carbide inserts are used. They are applied for drilling in semi hard and hard rock material (Fig. 3).

The diagram presented in Figure 3 illustrates dependences between drilling rate and the strength of sintered carbide to wearing by drilling in the rock mass. Most endurable are rounded-shape inserts, as they can perform well and long in very hard rock conditions. This type of inserts is most fit for very hard rocks, especially when associated with a DTH hammer. As compared to traditional methods (cogged bits), hammers with rounded-insert drillbits are invincible. The highest drillability was observed for cylindrical-insert bits, which are best fitted to soft rocks, and where drilling with such inserts advances considerably. This type of inserts is not good for drilling in hard rocks as the sintered carbide elements may get cracked, leading to fast wearing of the drillbit. Ballistic-shape inserts are most suitable for medium hard rocks, whereas semi-ballistic inserts are best for drilling in hard rocks. The plot in Figure 3 shows a theoretical application of each type of the drillbit inserts used with DTH hammers. In reality there are many other aspects deciding about most productive type of the drilling tool and economic as far as time of drilling is concerned. Rock layers frequently change in the course of drilling and pass from, e.g. soft to the hard ones. Therefore, each planned borehole should be addressed individually, whereas the tools and parameters should be so selected as to fully optimize the rate and cost of drilling.

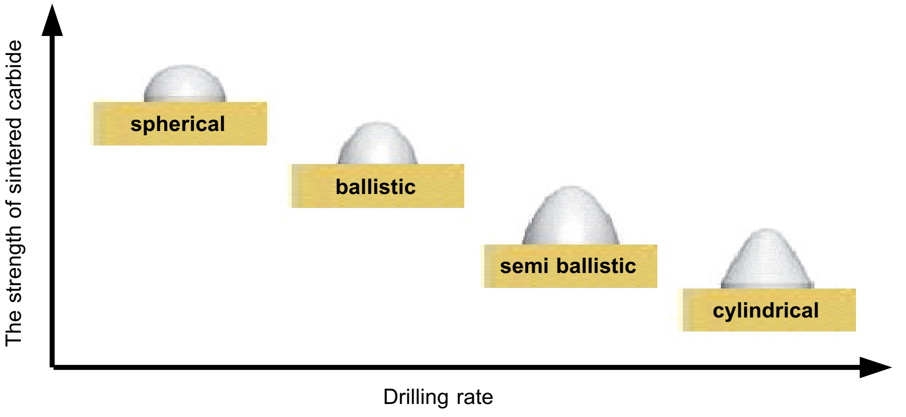

Fig. 3. Plot representing relations between drilling rate and strength of sintered carbide inserts to cracking [2]

Figure 4 illustrates inserts used for DTH drillbits, produced by Mincon. Apart from the Atlas Copco offer, there has been additionally presented a double-dome insert.

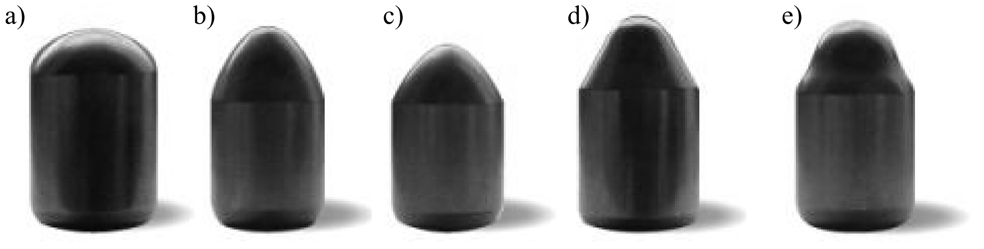

Fig. 4. Sintered carbide inserts for DTH drillbits by Mitsubishi: a) dome; b) ballistic; c) parabolic; d) conical; e) double-dome [3]

3. DRILLBIT FACE

Drillbits used for DTH hammer drilling can be divided not only in respect to the shape of the sintered carbide inserts, but also the shape of the drillbit face. Drillbits of various face shapes have been presented in Figure 5, and their descriptions are given in Table 1.

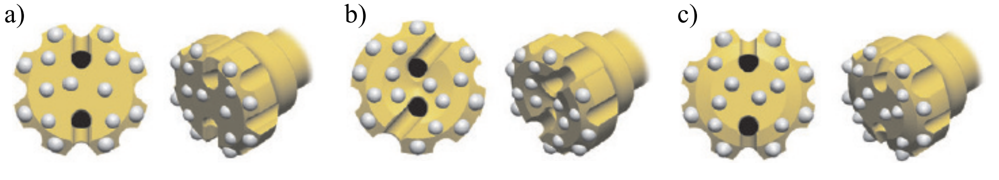

Fig. 5. Heads of drillbits [2]

Table 1

Drillbits vs. shape of the drillbit face [2]

Shape of drillbit face	Figure	Description
Flat	5a	To be used in hard, medium hard and abrasive rocks (e.g. granite, basalt and hard limestone)
Concave	5b	To be used in hard, medium hard and homogeneous rocks (e.g. granite, hard limestone). Good control of borehole axis deflection and washing of the bottom of the borehole
Convex	5c	To be used in soft and medium hard rocks, not in abrasive rock (e.g. shales, limestone, sandstones). Very good advance of drilling works

Accordingly, flat, convex and concave faces can be distinguished. Flat faces are used for drilling in hard and medium hard rocks; concave faces are used for all rock types, however, accounting for the shape of the inserts. Convex face drillbits are most frequently used for drilling in soft rocks, more rarely in medium hard and hard rocks. DTH drillbits by Mincon have been presented in Figure 6.

a) b) c) d)

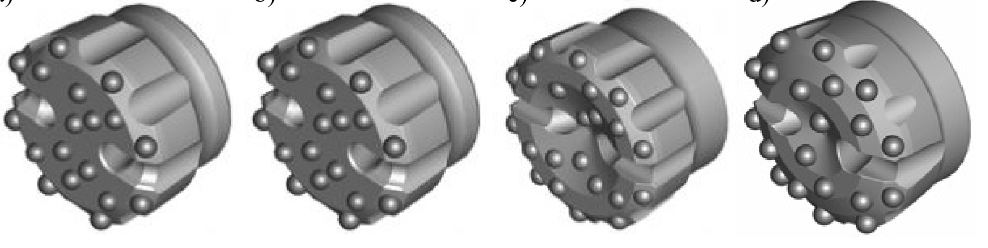

Fig. 6. Heads of DTH drillbits by Mincon: a) convex; b) flat; c) concave; d) with additional edge inserts [3]

4. PRODUCERS

The biggest producer of drillbits associated with DTH hammers is Atlas Copco. This company offers a wide range of DTH drillbits, which are fit for all possible applications. Five basic models are available (Fig. 7): concave, flat face, Speed Bit, concave and Rocket Bit.

These drillbits were designed for special applications in all work conditions and for all rock hardnesses. Accordingly, the flat-face drillbits associated with rounded sintered carbide inserts are most appropriate for drilling in hard and abrasive rocks. Speed Bits have the same design on the perimeter as the flat-face ones, i.e. are equipped with rounded inserts. They have ballistic inserts in the front, which allows for better penetration and better drilling advance. Convex face models are an alternative. In the HD model bigger inserts are disposed on the perimeter, whereas in DGR (Fig. 7) the peripheral inserts are placed in two overlapping rows. The Rocket Bits are used for all rock types. Cylindrical or ballistic inserts are used for drilling in soft or medium-hard rocks, whereas rounded inserts are preferred in hard rocks. Examples of drillbits produced by Atlas Copco have been presented in Table 2.

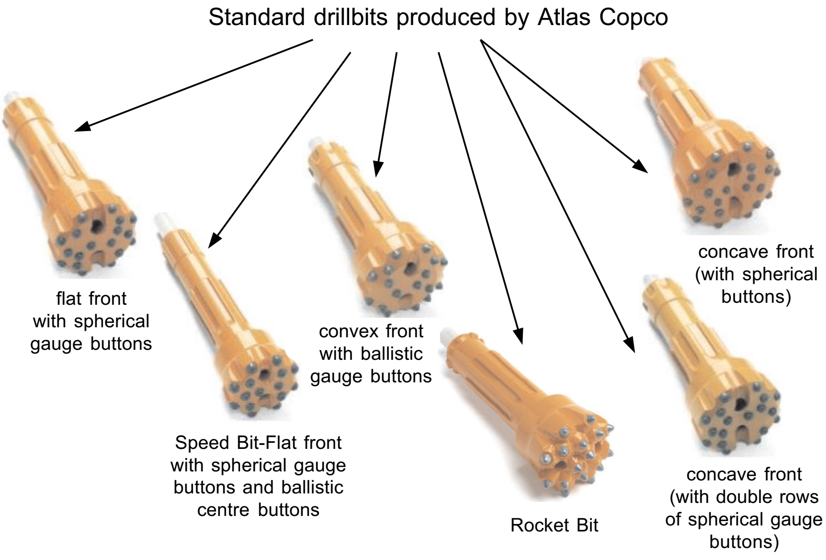

Fig. 7. Standard drillbits produced by Atlas Copco [2]

Table 2

Exemplary drillbits by Atlas Copco and their parameters [2]

Atlas Copco COP 54											
Diameter		Number × diameter of sintered carbide inserts [mm] ([in])				Inclination angle of sintered carbide inserts [°]			No. of nozzles	Mass	
[mm]	[in]	outer	inner	face	cone	outer	inner	cone		[kg]	[lb]
FLAT FACE											
130	5 1/8	8×16 (5/8)	–	8×16 (5/8)	–	35	–	–	2	15.9	35.1
134	5 1/4	8×16 (5/8)	–	8×16 (5/8)	–	35	–	–	2	16.2	35.7
140	5 1/2	8×16 (5/8)	–	10×16 (5/8)	–	35	–	–	2	16.6	36.6
149	5 7/8	8×16 (5/8)	–	9×14,5 (9/16)	–	35	–	–	2	17.1	37.7
152	6	8×16 (5/8)	–	8×16 (5/8)	–	35	–	–	2	17.8	39.25

Table 2 cont.

Atlas Copco COP 54											
Diameter		Number × diameter of sintered carbide inserts [mm] ([in])				Inclination angle of sintered carbide inserts [°]			No. of nozzles	Mass	
[mm]	[in]	outer	inner	face	cone	outer	inner	cone		[kg]	[lb]
SPEED BIT											
134	5 1/4	8×16 (5/8)	–	8×14,5 (9/16)	–	35	–	–	2	16.2	35.7
140	5 1/2	8×16 (5/8)	–	10×14,5 (9/16)	–	35	–	–	2	16.6	36.6
CONCAVE											
130	5 1/8	8×16 (5/8)	–	4×14,5 (9/16)	3×14,5 (9/16)	35	–	–15	2	15.8	34.8
134	5 1/4	8×16 (5/8)	–	4×14,5 (9/16)	3×14,5 (9/16)	35	–	–15	2	16.1	35.5
140	5 1/2	8×16 (5/8)	–	4×14,5 (9/16)	4×14,5 (9/16)	35	–	–15	2	16.4	36.2
146	5 3/4	8×16 (5/8)	–	4×16 (5/8)	4×16 (5/8)	35	–	–15	2	17.2	37.9
149	5 7/8	8×16 (5/8)	–	4×14,5 (9/16)	4×16 (5/8)	35	–	–15	2	17.5	38.6
152	6	8×16 (5/8)	–	4×16 (5/8)	4×16 (5/8)	35	–	–15	2	17.7	39.0
BALLISTIC CONVEX											
130	5 1/8	9×14,5 (9/16)	6×14,5 (9/16)	4×14,5 (9/16)	–	40	20	–	3	15.7	34.6
140	5 1/2	9×14,5 (9×16)	6×14,5 (9/16)	4×14,5 (9/16)	–	40	20	–	3	16.3	35.9
140	5 1/8	8×16 (5/8)	4×16 (5/8)	3×16 (5/8)	–	35	20	–	2	16.2	35.7
146	5 3/4	9×16 (5/8)	5×14,5 (9/16)	5×14,5 (9/16)	–	35	20	–	3	17.1	37.7

Drillbits for percussive-rotary drilling are also produced by such companies as Halco, Sandvik, Mincon, Bulroc, Rog Hog and Maxdrill.

5. CLUSTER HAMMERS

The cluster hammer (Fig. 8) consists of a number of hammers in one large-diameter housing. This type of hammer is used for large diameter, all-purpose drilling. Cluster hammers were designed and performed in Roanoke, Virginia, USA. Large diameter drilling technology is commonly applied in North America, Australia and Far East, though more and more European construction companies uses this technology as quicker, easier and cheaper than its other counterparts.

The large diameter boreholes range between 311 mm and 3048 mm, but their upper limit is connected with the logistics and transport of big tools. Hammers consist of modules and have a wide range of configuration possibilities, depending on the application type. The main producer of cluster hammers is Atlas Copco. There are single hammers for large--diameter boreholes, e.g. Secorc QL200 or QL300, or tools equipped with four or more 8-inch hammers (e.g. Secorc RC50). The serial cluster hammers accessible on the market stay within the range of 711 mm to 3048 mm. The DTH hammers are disposed in the housing and rotate along with it. Drillbits are mounted at the bottom of hammers. They are also rotating together with the tools and constantly taking different positions. This results in their even wearing. The mass of the cluster hammers depends on diameter but stays within the range of 2.5 Mg to 8.2 Mg. Hammers are mounted on rotary rigs, which are used for spiral drillbit operation to 1.2 m of diameter or on piling machines.

Fig. 8. Cluster hammer [2]

As in the case of regular DTH hammers, also cluster hammers need compressed air. However, a bigger jet of air is needed for large-diameter drilling. For instance, a borehole 1 m (40") in diameter needs about 1400 dm^3/s of air at 10 bar, which regular single compressors cannot provide. Therefore, a number of lower-capacity compressors should be connected.

The removal of cuttings in the course of drilling with cluster hammers can be realized twofold. In the first solution the air removes the cuttings through the annular space between the borehole wall and the cluster hammer with the outer drum (cage Calyx). In the course of drilling the cuttings are collected in the upper drum (right air circulation) (Fig. 9). In the other case the cuttings are removed by special holes disposed in the lower part of the cluster hammer head (the reverse (left) air circulation) (Fig. 10).

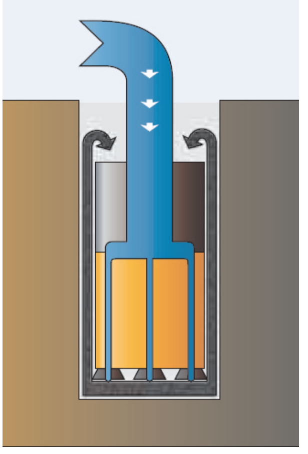

Fig. 9. Scheme of right air circulation [2]

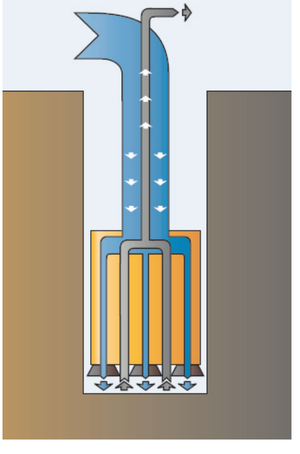

Fig. 10. Scheme of reverse air circulation [2]

Cluster hammers can be used for making piles, columns, pylons, foundations, rock pockets, strip footings, caissons, bridge pillars, shafts. Apart from a wide range of application, hammers also have a number of advantages making them even more attractive, i.e.: easy transport, easy handling and what is very important, high rate of drilling (even three times faster than other drilling tools). Unlike drillbits, hammers are doing very well in various types of rock. The drillbits are fastened separately on the face of the hammers thanks to which one can quickly and easily replace the damaged drillbit or fix the damage. Hammers can be also used for overworking pilot wells. Importantly, hammers are not heavy therefore practically all types of geotechnic rigs can be used. Parameters of exemplary cluster hammers have been presented in Table 3.

Table 3

List of parameters of selected models of cluster hammers [2]

Model	Diameter		Length		Mass		Pressure / yield	
	[mm]	[in]	[mm]	[in]	[kg]	[lb]	[bar/psi]	[dm^3/s]
CDS36 5/4	915	36	1600	63	2.8	6.3	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	700 947 1225 1532 1869
CDS42 7/4	1067	42	1600	63	4	8.8	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	978 1326 1715 2145 2616
CDS46 7/4	1169	46	1600	63	4.3	9.5	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	978 1326 1715 2145 2616
CDS48 7/4	1219	48	1600	63	4.5	10	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	978 1326 1715 2145 2616
CDS54 9/5	1372	54	1600	63	5.8	12.7	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	1257 1704 2205 2758 3364
CDS60 11/5	1524	60	1600	63	7.1	15.7	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	1537 2083 2694 3370 4111
CDS70 13/5	1778	70	1600	63	9.1	20	6.9/100 8.6/125 10.3/150 12.1/175 13.8/200	1816 2462 3184 3983 4859

6. CONCLUSIONS

1. Drillbits are the most vulnerable elements in percussive-rotary drilling. Presently, stronger and more endurable drillbits are produced and used, which increases the interest in the use of down-the-hole (DTH) hammer techniques.

2. The use of very strong sintered carbide inserts allowed for the production of drillbits withstanding the percussive-rotary drilling operation.
3. Among the most commonly applied drillbits are: flat-face, concave and convex ones. The shape of the face and the sintered carbide inserts determine the use of the drillbit, accounting for the hardness of rocks to be drilled.
4. Cluster hammers are used for large-diameter percussive-rotary drillings. This type of hammers is composed of a number of component DTH hammers. In the course of large-diameter drilling the entire cluster hammer is rotating, along with each DTH hammer components.

REFERENCES

[1] Gonet A., Śliwa T., Stryczek S., Sapińska-Śliwa A., Jaszczur M., Pająk L., Złotkowski A.: *Metodyka identyfikacji potencjału cieplnego górotworu wraz z technologią wykonywania i eksploatacji otworowych wymienników ciepła* (praca zbiorowa pod redakcją Andrzeja Goneta). Wydawnictwa AGH, Kraków 2011.

[2] http://pol.atlascopco.com (2012).

[3] http://www.mincon.com (2012).