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REVERSE CIRCULATION DTH HAMMER DRILLING TECHNOLOGY

Summary. The technical characteristics and operational principal of the reverse circulation DTH hammer drilling technology is introduced in this paper. It is that with the computerized emulation and the simulation technique to assist the drilling tool design, so the optimum designed DTH hammer gets stable performance, and the drilling bit is with good reverse-circulation ability, and further more, it has already developed serialization products. The reverse circulation DTH hammer drilling technology has been fully applied in areas such as the geological exploration core in complex formation, hydrological drilling wells, and large diameter rock embedding piles drilling in hard rock, and obviously, it is achieved favourable economic and social benefits.

TECHNOLOGIA WIERCENIA URZĄDZENIEM DTH Z CYRKULACJĄ ZWROTNĄ

Streszczenie. W artykule scharakteryzowano technologię wiercenia z cyrkulacją zwrotną. Urządzenie DTH zapewnia dobrą wydajność, co decyduje o jego znaczeniu ekonomicznym. Wiercenia ze zwrotną cyrkulacją są stosowane w poszukiwaniach geologicznych (z rdzeniowaniem) w formacjach o złożonej budowie, w przypadku studni, odwiertów wielkośrednicowych, a także dla skał o dużej twardości.

1. Introduction

The reverse circulation DTH hammer drilling technology is an important constituent part of the Multi-Tech air drilling technology, and more importantly, it is a major breakthrough of air drilling technology in method of broken rock. It is combined with DTH impacting breaking rock, flushing medium full hole reverse circulation and continuous coring-three

advanced drilling techniques into one system, and naturally it has become an integrated high-tech drilling techniques. The hollow-through DTH, reverse circulation bit, and dual-wall drilling tool are constituted the center channel, then the flushing medium along with the center channel to form the reverse circulation, so it is realized the core transportation in the process of drilling and effectively solved the problem of the orifice dust pollution. At present, the drilling technology developing rapidly, the application areas are gradually expanded, and it has got good applications in drilling engineering areas such as geological core exploration, water well drilling and foundation engineering.

2. Key Technologies of Reverse Circulation DTH hammer Drilling

2.1. Structural design on the hollow-through DTH hammer

The key of structural design on the hollow-through DTH is the hollow pore design. The center of hammer's all parts is the hollow-through tube structure. The hollow-through pore and the pre-and-post air chambers are completely closed, and the inner tube formed the hollow-through pore are crossing all parts, with its the upper part connecting with the inner tube of drill pipe and the lower part cottage grafting drilling bit to form the reverse circulation channel. At the same time, the inner tube has gas distribution function.

2.2. Computerized emulation of DTH hammer

Firstly, with the basic theory and mathematical formula to build up the mathematical model, then based on the finite difference theory to develop the computer software, finally, it is achieved the computerized emulation on hammer dynamic process, piston reciprocating motion law and hammer performance parameters. With the computer assisted the optimum design, the actual test parameters are highly anatomized with the computerized emulation parameters. The working performance is good, and the effective heat efficiency is high, so consequently design of hammer becomes scientific. It changes the traditional design methods, shortens the development cycle, saves the study cost and optimized the hammer performance.

2.3. Reverse circulation drilling mechanism and reverse circulation bit design

In order to further research reverse circulation mechanism, it is built up reverse circulation drilling simulation experiment table. And through the experiment table, some are got further studied such as the reverse circulation formation mechanism, the relationship between compressed air parameters and carrying cores ability, and the effects of the bit structural parameters on reverse circulation. The reverse circulation law of the flushing medium is revealed, and based on the multi-nozzle ejector principle it is innovated to design the reverse circulation bit (in flg.1). Simultaneously, through introducing the CFD theory, the base flow field of the bit is simulated and the parameters are calculated with CFD software. The computerized emulation shortens the development cycle, and with the virtual technology substitute for the prototype trial-production and the practicality experiment. At present, the products of the hollow-through DTH hammer have been serialized, and these included as follows: 11 kinds of GQ DTH hammer which is shown in table 1, various reverse circulation bits applicable for different formation and demands on cores recovery.

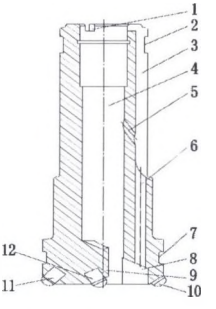

Fig. 1. Structure diagram of reverse circulation bit
Rys. 1. Budowa świdra z cyrkulacją zwrotną

Table 1

Main technical parameter of GQ specification DTH

Model	Inner hole diameter	Hole diameter	Hammer length	Impact energy	Impact frequency	Air consumption (m^3/min)	Operation pressure	Application field
GQ-89	33 mm	93-120 mm	1222 mm	158 J	19 Hz	4.8	1.4 MPa	mineral
GQ-108	38 mm	112-132 mm	1255 mm	260 J	19 Hz	9	1.45 MPa	mineral
GQ-127	44 mm	132-154 mm	1264 mm	410 J	18.8 Hz	11	1.4 MPa	mineral
GQ-146	55 mm	152-186 mm	1267 mm	550 J	17 Hz	12	1.1 MPa	mineral
GQ-160	60 mm	165-200 mm	1302 mm	640 J	16 Hz	13	1.0 MPa	water-well
GQ-200	60 mm	200-250 mm	1468 mm	720 J	18 Hz	14	1.0 MPa	water-well
GQ-250	62 mm	250-350 mm	1459 mm	1052 J	16 Hz	17	1.05 MPa	water-well
GQ-320	89 mm	325-600 mm	1549 mm	2190 J	19 Hz	46	1.3 MPa	petroleum

3. Reverse Circulation DTH Hammer Continuous Coring Drilling

3.1 The basic principle of reverse circulation drilling

The structure principle chart of the hollow-through DTH is shown in fig.2. The compressed air is firstly crossing the dual path air-water swivel 2, then along dual-wall drill rod 5 entering into the outer space of the upper joint of the hollow-through DTH, pushing the check valve 6, full of the annular channel of the outer cylinder and inner cylinder 8, finally, through the radial hole of the inner cylinder 8 entering into the pre-and post air chambers to push the piston 9, with reciprocating motion, the impact energy is got. The waste gas in the pre-and post air chambers is respectively exhausted to the annular channel between the piston 9 and the inner tube 7, then entering into the ring groove of the drilling bit, through the channel at the bottom of the spine groove, and at last, is exhausted by the discharge port of the drilling bit. With the strong pumping action of the pumping hole in the drilling bit, the air is carrying the core sample entering the center of the drilling bit, then through the center channel of the dual-wall drill rod then by the gooseneck tube 3 of the swivel and sullage pipe 1, and finally discharged to the surface equipment that is used for collecting core samples.

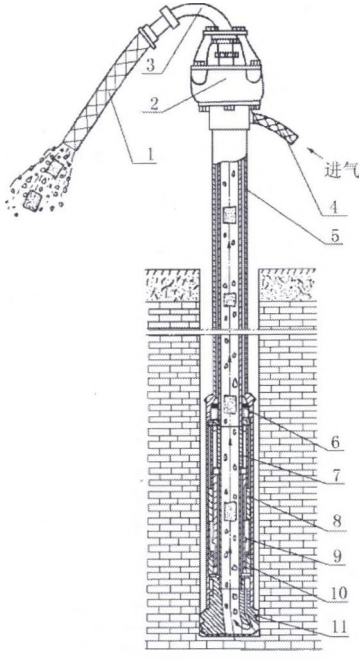

Fig. 2. Structure principle chart of hollow-through DTH hammer: 1-sullage pipe, 2- dual path air-water swivel, 3- gooseneck tube, 4-air inlet hose, 5-dual-wall drill rod, 6- check valve, 7-inner tube, 8-inner cylinder, 9-pistion, 10-bush, 11-reverse circulation bit

Rys. 2. Budowa otworu z urządzeniem wiertniczym DTH: 1 – odpływ szlamu, 2 – dwubiegowa pasterka powietrzno-wodna, 3 – szyjka płuczkowa, 4 – wpust powietrza, 5 – żerdź dwuścianowa, 6 – zawór zwrotny, 7 – rura wewnętrzna, 8 – cylinder wewnętrzny, 9 – tłok, 10 – tuleja, 11 – świder z cyrkulacją zwrotną

3.2. Reverse circulation DTH hammer drilling applied in complex formation geological core exploration

The geological core exploration in complex formation, especially in the extreme complex formation is always the construction problems on the drilling field (fig. 3). With the small-caliber hollow-through DTH hammer and the matching dual-wall drill pipe to execute the reverse circulation continuous coring drilling, it is solved a series of drilling technical problems such as the low drilling efficiency in the process of complex formation geological exploration, the low core recovery percentage, the poor quality of the core (fig. 4), hole accident current mutation, drill tools with a short life-span, the high construction costs, the long construction period and so on, and got the good application effect.

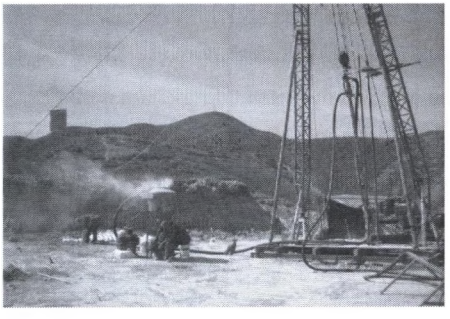

Fig. 3. Construction site of reverse circulation DTH hammer
Rys. 3. Miejsce pracy urządzenia wiertniczego DTH z cyrkulacją zwrotną

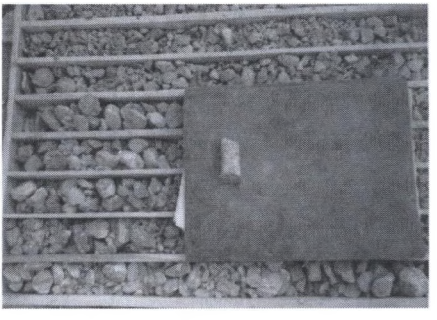

Fig. 4. Geological exploration cores
Rys. 4. Rdzenie z wierceń poszukiwawczych

In the different complex strata of mining area, this technology is conducted massive productive experiment, and completed plenty of experiment workload (fig. 5). It is found that every drilling indicator is excellent and good, therefore, the difficult problems of exploration technology in complex strata is settled. The drilling efficiency is increased by 3-10 times and the availability of penetrating time is raised by 2-3 times comparing with the conventional diamond drilling. Reverse circulation is stable, and the core recovery percent core is over 98%. According to the different coring

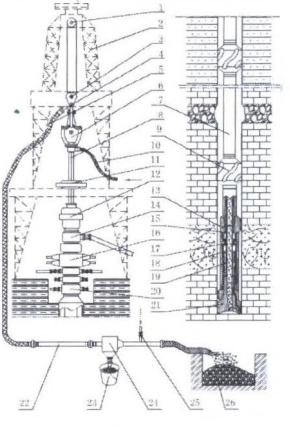

Fig. 5. Principal of the reverse circulation DTH hammer drilling system
Rys. 5. Zasady cyrkulacji zwrotnej w systemie wiertniczym DTH

requirements, it could be obtained cores and core samples. the core and core sample is true and credible. Thanks to the double-wall drill pipe, the hole wall is free from the disturbance, effectively protecting the hole wall. the hole accidents became few. The construction cycle is greatly shortened. The Comprehensive drilling cost is dropped into1/3-1/2 of the diamond drilling cost.

3.3. Reverse circulation DTH hammer drilling technology applied in water well drilling

By using of the reverse circulation DTH hammer drilling, many demanding prompt technical problems of bedrock water well drilling is efficiently resolved. Through productive applications of the DTH reverse circulation drilling, it is proved that compared with normal circulation drilling, the average drilling efficiency is increased by 64 %, and drilling cost per meter is reduced by 30%-40%, and the collecting rate of drill core is over 98%. In the large diameter water well drilling, this drilling method have many outstanding characteristics.

(1) During drilling process, the flushing medium in drilling tools is closed cycle, which is benefit to protect hole wall and to avoid aquifer blocking, and easy to drill through the fracture and broken formation.

(2) The hollow of the DTH and the dual-wall drill rod are served as the reverse-circulation channel, and with the same diameter, its basal area is small. For a limit air supply amount, the upwards going air velocity is raised, and the ability of slag discharge is so improved that the bottom hole chippings could be avoided crushing repeatedly. The rock fragmentation efficiency of hammer is promoted.

(3) When drilling is in process, it is to avoid the pollution of the rock power running away and the blowout as drilling under water, which is in favor of the environmental protection.

(4) The reverse circulation DTH hammer drilling technology makes the process of pumping and well washing simplified, and water yield is greatly ratted. For the water well exploration of exploration-production combination, the continuous coring drilling could be fulfilled.

4. Prospect of Reverse circulation DTH hammer drilling used in oil and gas exploration

Recently, the DTH normal circulation drilling has been applied in the oil and gas exploration field and got good application result. But the technology also has disadvantages

such as high energy consumption, high cost and working yard crowding, which limits its extensive application. Practice has proved that in large diameter drilling, the reverse circulation DTH hammer drilling technology has unique advantages:

(1) Under the same well diameter, the air consumption of air reverse circulation drilling is about 1/5-1/2 of air normal circulation drilling, so the number of air compressors and fuel consumption can be reduced;

(2) Using DTH hammer to penetrate hard rock is always efficient. The penetrate rate is usually 3~4 times as high as normal rotary drilling, which means less cost of money and time.

(3) As the fluid medium in drilling tools is closed cycle, when encountered the karst cave or the big fracture, drilling will not be terminated for gas leakage;

(4) Overcoming the damage to strata caused by drilling fluid, foam or high-pressure air of the conventional drilling, it is conducive to improving the single well production.

There are ribs on the upper and lower subs of the DTH hammer to prevent the bend of hole, and hard alloy embedded in the surface of the hammer to trim the wall of hole. And also, drill collar and stabilizer are placed above the DTH hammer so as to verify the straightness of the hole.

5. Large Diameter Wet DTH Hammer Reverse Drilling

Large diameter hard rock drilling is the technical problem in engineering construction, because of low penetration rate when using conventional drilling methods, even unable to get drill footage. It is apparent to found that by utilized simulation of emulator program and optimum design makes working parameters of FGC-15 large diameter wet DTH hammer are satisfied all requirement of the lager diameter of drilling hole rock fragment (fig. 6, 7). Simultaneously, the dynamic parameters, that is, air compressor parameters meet national conditions. Through many productive experiments, this drilling technology can be popularization and application.

The drilling system assembles 4 advanced technologies:

(1) Large diameter DTH hammer broken rock. The huge energy caused by the hammer makes the rock fully cracked, and the penetration rate is greatly improved.

(2) Compressed air circulation system and mud medium system are relatively independent. Take the pump suction reverse circulation or air-lift reverse circulation in order to ensure higher upwards going flow rate and hole-bottom cleanness.

(3) Mud medium wet circulation protecting hole wall. When DTH hammer drilling in process, mud medium in the hole using to protect the hole wall and balance with formation pressure, shieled the hole wall in stabilization and safety.

(4) Compressed air closed circulation decreasing air pressure. Compressed air in drilling tools forms closed cycle, and the air pressure can't be influenced by the hole resistance and the fluid column pressure. The air pressure is only determined by the pressure drop in air pipeline and the work pressure dropof DTH hammer.

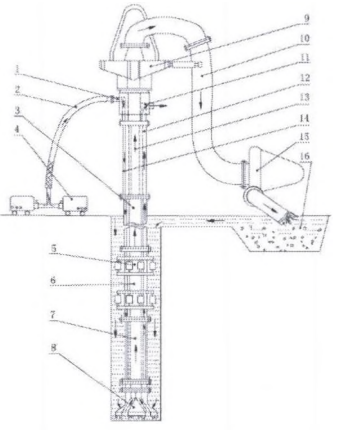

Fig. 6. FGC-15 large diameter reverse circulation DTH hammer drilling system

Rys. 6. Wielkośrednicowy system cyrkulacji zwrotnej FGC-15 w urządzeniu wiertniczym DTH

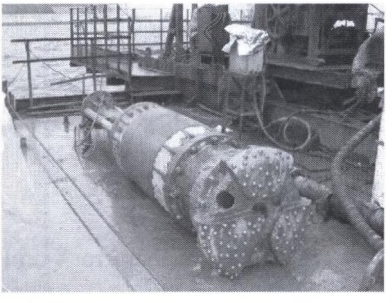

Fig. 7. Large diameter DTH hammer and bit

Rys. 7. Wielkośrednicowe urządzenie wiertnicze DTH i świder

The drilling system has been used in Production tests from 1990, and in nearly 20 projects of rock-socketed filling pile, it is got favorable application effect. Average drilling rate in hard rock is about 0.6-1.3m/h, which is increased by 10-20 times comparing with conventional drilling methods. The pile hole quality is good, and rock-socket is reliable. It can shorten construction period is short, and construction cost is low. Obviously, it has a wide application prospect.

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