A NEW METHOD FOR CLASSIFICATION OF ROCK DRILLABILITY[①]

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ABSTRACT

A New method of rock drillability classification for impregnated diamond drilling is recommended. The essence of the method is comparing the area of the slots cut respectively on a standard synthetic rock sample and the rock sample being classified by one diamond saw to determine the rock drillability in diamond core drilling. This method has the advantages of good in simulation and stable in comparison standard.

Key words: rock drillability classification diamond core drilling cutting-comparison method

1 INTRODUCTION

Diamond core drilling is important for exploring mineral resources, and rock drillability is an essential prerequisite for the design and construction of the drill engineering. Many investigations on rock drillability have been carried out at home and abroad, however receptive progresses have rarely been gained since 1960's in spite of many investigation methods, such as single mechanics index measurement, multiple mechanics index measurement, micro-drilling, productive investigation, and so on, have been used. The reason lies in the fact that all the investigation method used so far were indirective method, which cann't really reflect the essential characteristics of rock drillability and never studied the nucleus of the problem. Therefore, it is the purpose of the present paper to propose a new classification method for rock drillability, of which a directive cutting-comparison method was used and all indirectively extrinsic and unilateral methods were given up.

2 EXPERIMENTAL

2.1 *Experimental Principle*

It is very necessary to find out a directive comparison standard for determing the drillability of various rocks. However, both rock and diamond bit fail to be such comparison standard because rocks are inhomogeneous and the performance of any diamond bit varies with drilling. Therefore, a synthetic material, acid-resistant porcelain, was selected to be the comparison standard material instead of rock. The idea of the method lies in the fact that, cutting a rock sample and a synthetic porcelain rod with the same diameter of the rock sample simultaneously by a diamond saw, and using the ratio between the area of the slots cut in the porcelain rod and the rock sample as an index for determing the rock drillability. Thus, the slot area of the rock sample greater than that of the porcelain rod means the rock is easier to drill than the porcelain rod and the drillability of the rock must be lower than that of the porcelain rod.

The above idea was based on the follow-

① Manuscript received Oct. 25, 1992

ing thoughts.

(1) Cutting a rock sample with a diamond saw can simulate the fragmentation process of rock during drilling, and more a rock which is easy to be cut by a diamond saw must also be easy to drill with a diamond bit and vice-versa;

(2) The performances of the diamond saw give very small influence to the measured area ratio of the slots when cutting the rock sample and the porcelain rod simultaneously using the same saw;

(3) The property of the porcelain rod could be stable because it was made in special factories using a standard productive technology, thus a liable comparison standard for the classification of rock drillability was provided.

The characteristics of the above idea lies also in that, the drillability is determined with the comparative index, i. e. the ratio between the area of the slots cut simultaneously in rock sample and porcelain rod with a diamond saw, but not with the cutting speed of the saw; and also the drillability is determined by a standard porcelain rod with stable properties but not by the saw, thus resulting in the measurement error to be very small. In addition, the cutting-comparison idea is favourable to solve the discrepancy between simulation and standarization, and make the classification simpler and easier than any other classification method of rock drillability.

2.2 *Experimental Method*

As shown in Fig. 1, the rock sample being tested and the porcelain rod as a comparative standard were cut simultaneously under the same thrust (3 N) using a diamond saw with a speed of 1 450 r/min (a linear velocity of 15 m/s). The diameters of both rock sample and porcelain rod were 18 mm. The slot area was measured after each cutting, and then the drillability coefficient A was calculated as follows.

$$A = (S_P/S_R) \cdot k \tag{1}$$

where S_p —the slot area of the porcelain rod;

S_R —the slot area of the rock sample;

k —conversion coefficient, let $k = 8$ because the porcelain rod is ranked 8th among a classification of rock drillability with 12 classes.

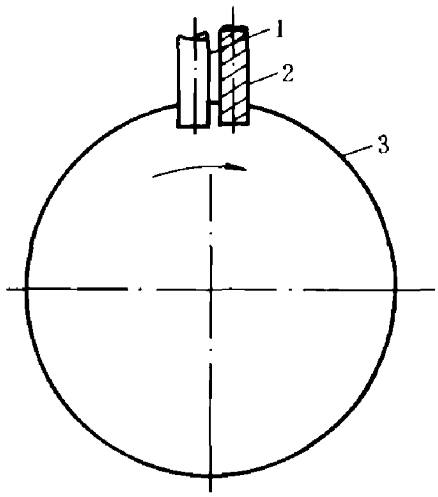

Fig. 1 A schematic diagram of the cutting-comparison method

1—porcelain rod; 2—rock sample; 3—diamond saw; F —advancing thrust, 3 N

2.3 *Experimental Identification*

29 rock types from six geological teams were tested using cutting-comparison method and then calculated using equation (1), the results are listed in Table 1.

For identifying the feasibility of the classification method of rock drillability, additional experiments were carried out with micro-drilling, i. e. drilling the rock sample and the porcelain brick with micro-drill bit to gain a drillability coefficient B and C respectively, where B represents the ratio between the thrusts applied to the hole bottom during drilling the rock sample and porcelain brick by uniform velocity, and C the ratio of the wear of the micro-drill bit in drilling rock sample and porcelain brick respectively, namely

$$B = kp_R / p_P \quad (2)$$

$$C = w_R / w_P \quad (3)$$

where p_R — hole bottom thrust of micro rock drilling;

p_P —hole bottom thrust of micro porcelain drillig;

w_R —wear of micro bit for drilling rock;

w_P —wear of micro bit for drilling porcelain brick.

The micro-drilling was carried out in a sequence of porcelain brick→rock sample→porcelain brick→rock sample…. The outer and inner diameters of the diamond micro bit were 31 mm and 18 mm respectively. The penetration rate in rock samples and porcelain brick were 1.6 m/h under a condition of certain amount of drilling fluid. The calculated drillability coefficients A, B and C based on experiments are listed in Table 2.

Regression analysis based on Table 2 shows that the variation of value A agrees very well with values B and C, which implies the experimental result of cutting-comparison method proposed by the author is linearly related with those of the micro-drilling method, and the drillability coefficient (A) could be used as an index for classification of rock drillability in diamond drilling because the micro-drilling method has already been used for such classification.

3 DISCUSSION

3.1 *The Relationship Between cutting-Comparison Method and Micro-drilling Method*

Value A calculated upon the result of cutting-comparison experiments represents the easy or uneasy degree of abrading rock by diamond; value B based on micro-drilling represents the easy or uneasy degree of abrading rock by diamond bit, which is not only determined by easy or uneasy degree of abrading rocks by diamond but affected by the ability of the rock's abrading the matrix (in the fact cutting's abrading matrix); and value C represents the ability of rock's abading bit matrix. The reletionship among A, B and C can be expressed more clearly as

$$\left.\begin{aligned} A &= \sigma B \\ \sigma &= f(C) \end{aligned}\right\} \quad (4)$$

where σ is a corrective coefficient related to C.

Since value C affects the self-sharpening ability of impregnated diamond bits, so also affects value B, which repersents easy or uneasy degree of the bits' drilling.

The reason of value A being not often in good agreement with valve B lies in that, the micro-drilling was carried out according to a sequence of rock sample→porcela in brick→rock sample→porcelain brick…, the measured data were affected greatly by the varied bits' performance. But the cutting of the rock sample and porcelain rod were carried out simultaneously by the same diamond saw, the variation of the diamond saw behaviours gives a little, if any, effect to the measured data, so the measured data of cutting-comparison method were preciser than those of the micro-drilling method. Therefore, it is not reasonable to replace the drillability coefficient A with coefficient B for classifying rock drillability, in spite of a very good linear relationship existing between them. In addition, the cutting-comparison method gives an objective standard, which is an unique characteristics among classification methods of rock drillability reported so far.

Table 1 Drillability coefficients (*A*) of 29 rock types

No	rock types	*A*	No	rock types	*A*
1	chalcedony	15. 3	16	strongly silicified limestone—3	8. 5
2	silicious rock	13. 7	17	middlely silicified limestone—1	6. 9
3	compact state quartzite	10. 7	18	middlely silicified limestone—2	8. 0
4	quartzite	9. 8	19	middlely silicified limestone—3	8. 4
5	granite with container	9. 0	20	weakly silicified limestone—1	5. 4
6	pyroxenite	8. 3	21	weakly silicified limestone—2	5. 5
7	coarse-grained granite	8. 1	22	crystalline limestone	5. 1
8	granite with container	7. 9	23	limestone	6. 7
9	middle-grained plagioclase granite	7. 6	24	quartzy sandstone	8. 3
10	middle-grained pophyritic granite	7. 4	25	grit sandstone	4. 5
11	middle-coarse grained biotite granite	6. 1	26	granite—1	4. 9
12	shale	57	27	black silicified rock	5. 2
13	dolomite	3. 9	28	fine-grained sandstone	4. 2
14	strongly silicified limestone—1	11. 8	29	granite—2	7. 1
15	strongly silicified limestone—2	9. 1			

Table 2 Drillability coefficients *A* , *B* and *C*

Rock	*A*	*B*	*C*	rock	*A*	*B*	*C*
chalcedony	15. 3	21. 2	9. 3	strongly silicified limestone—3	8. 5	6. 7	4. 9
silicious rock	13. 7	17. 4	5. 6	middlely silicified limestone—1	6. 9	5. 7	1. 13
compact state quartzite	10. 7	13. 5	4. 0	middlely silicitied limesfone—2	6. 34	9. 4	4. 9
quartzite	9. 8	11. 9	2. 6	middlely silicitied limeshone—3	7. 37	9. 7	3. 0
granite with container	9. 0	8. 5	1. 2	weakly silicified limestone—1	5. 4	4. 5	3. 9
pyroxenite	8. 3	8. 6	1. 2	weakly silicified limestone—2	6. 5	6. 5	3. 9
coarse-grained granite	8. 1	8. 5	1. 3	crystalline limestone	5. 1	4. 8	2. 6
granite without container	7. 9	8. 2	1. 3	limestone	6. 7	4. 3	—
middle-grained plagioclase granite	7. 6	7. 4	1. 3	quartzy sandstone	8. 3	6. 7	1. 4
pophyritic granite	7. 4	7. 6	0. 9	grit sandstone	4. 5	1. 4	3. 9
middle-coarse grained biotite granite	6. 1	6. 3	0. 9	granite—2	7. 1	8. 8	3. 9
shale	5. 7	5. 1	0. 6	black silicified rock	15. 2	13. 9	6. 1
dolomite—1	3. 9	4. 0	0. 3	fine-grained sandstone granite—1	4. 2	5. 5	0. 7
strongly silicified limestone	11. 8	9. 7	2. 6	granite 1	4. 9	5. 8	2. 0
strongly silicified limestone—2	9. 1	8. 6	1. 5				

With respect to value *C* , though there is approximate linear relationship between *A* and *C* values, in general, it is not suitable for a specific rock, because some rocks have same values *A* , but their values *C* have very large difference. Therefore it is impossible to classify rock drillability using values *C* , yet it is very useful for guiding the design of the impregnated diamond bit since value *C* represents the ability of rock abrading matrix, as mentioned above.

3.2 *Examples for Application of Cutting-comparison Method*

(1) A number of impregnated synthetic diamond core drilling bit(hereafter diamond bit) were used to drill a middle-coarse grained sandstone with a service life of 0.2 m/bit in No. 1 coal geological team, Hunan province. Thereafter, some diamond bits manufactured by another factory were used with an increasing service life of 2 m/bit. For improving the service life further, the author measured the sandstone with cutting-comparision method and got the drillability coefficients $A=5.7$, $C=6.9$. These results revealed that the main reason for a very short bit service life lies in the sandstone having a high abradability to the matrix. Thus the author designed a new diamond bit with strengthened matrix and got a high service life of 25～30 m/bit.

(2) No. 607 geological team used a diamond bit to drill the quartzitic-diorite with a low drilling efficient of 1.62 m/h and a service life 25.2 m/bit. The author measured the rock's $A=11.7$ and $C=3.7$, which showed that the quartzitic-drorite having a very strong abradability for diamond and having middle abradability for matrix. Based on A, C data, the author developed a new diamond bit with adjusted parameters for replacing the old bit and gained a high drilling efficiency of 3.66 m/h and a service life of 30.5 m/bit.

(3) No. 332 geological team, Anhui province, drilled in three kinds of extremely hard rocks with an average service life of 15 m/bit and very low drilling rate, even no footage. The values A, C of extremely hard quartizite were 17.0 and 0.92, of red granite 27.0 and 11.7, of grey granite 9.2 and 0.91 respectively. In the light of the measured A, C data, 15 diamond bits were designed and tested gaining a mean service life of 30 m/bit (max up to 52 m/bit), and drilling rate 2.6～3.8 m/h.

4 CONCIUSIONS

(1)The discrepancy between simulation and standardization in measuremant method of rock drillability has been solved by the using of cutting-comparison method, which has not only a concrete comparison standard but also an unique simulation feature;

(2) Cutting-comparison method classifies the rock drillability in the light of easy or uneasy degree of rock being abraded by diamond which overcomes the discrepancy of un-agreeing in rock drillability classificafion;

(3)The precision of measurement in cutting-comparlson method is high, its measared result gives clearly a quantity conception;

(4)The cutting-comparison method has an objective standared for evaluating the rock drillability;

(5)The apparatus of the cutting-comparison method is simple, cheap and easy for use.