RESEARCH ON DRILLING TECHNIQUES FOR DEEP GEOTHERMAL WELLS

Hirokazu KARASAWA, Tetsuji OHNO and Hideo KOBAYASHI

National Institute for Resources and Environment

ABSTRACT

The objective of this research is to develop polycrystalline diamond compact (PDC) bits for deep geothermal well drilling, especially for downhole motor drilling. Drilling and durability tests have been conducted using 66 mm-dia PDC core bits, 98.43 and 142.88 mm-dia PDC full-face bits. On the basis of these test results, a PDC full-face bit with diameter of 142.88 mm was redesigned and fabricated to improve the bit performance. The durability tests revealed that this bit has the bit-life of about 17 m in hard and abrasive granite drilling.

INTRODUCTION

Thermal stability of roller cone bits is relatively low; therefore, their bit-lives often decrease considerably in the drilling of geothermal wells with the formation temperature above 350-deg C. On the other hand, the applications of PDC bits for geothermal well drilling are limited due to insufficient cutter strength, even though they have thermal stability up to 700-deg C.

We have conducted drilling and durability tests to develop PDC full-face bits for geothermal well drilling (Karasawa and Ohno, 1995, Karasawa et. al., 1996). This research is divided into four stages. We first investigated the effect of the cutter diameter on the bit performance at high rotary speeds using 98.43 mm-dia PDC full-face bits. Second, 142.88 mm-dia PDC full-face bits were fabricated and tested based on this investigation. In addition, durability tests with granite were conducted to understand points for further improvements of 142.88 mm-dia bits using one of test bits. The tests revealed that not only the bit design must be improved, but also PDC cutters with improved strength is necessary to improve the bit performance significantly. Third, the performance of polished and conventional PDC cutters was evaluated using 66 mm-dia core bits. Finally, a 142.88 mm-dia PDC full-face bit was redesigned and fabricated using the polished PDC cutters based on the test results mentioned above. The durability tests were carried out to evaluate the life of the bit. This paper reports on conduct and the results of these tests.

TEST RESULTS

Effect of cutter diameter on bit performance

PDC bits available for downhole motor drilling must be designed and fabricated so as to be able to rotate at high speeds of more than about 100 rpm. An idea for fabricating these bits is both decreasing the cutter diameter and increasing the number of cutters brazed on a bit body. Thus, the effect of the cutter diameter on the bit performance was investigated using 98.43 mm-dia PDC full-face bits. Figure 1 shows the test bits. Details of these bits are recorded in Table 1 from Nos.1 to 5. Figure 2 is one example of the test results. This figure shows the relation between the cutter diameter and the penetration per revolution when Sori granite (the uniaxial compressive strength: 158-209 MPa) was drilled at the rotary speed of 50 to 400 rpm. It is noted that the penetration per revolution of all bits decreases considerably at 300 and 400 rpm as compared to the data at less than 200 rpm. Also noted is that the penetration per revolution of bit Nos.1 to 3 is larger than that of bit Nos.4 and 5 at 300 and 400 rpm. The vibration of bit Nos.4 and 5 while granite drilling was greater than that of other bits at 300 and 400 rpm.

Performance of 142.88 mm-dia bit

In the granite drilling using the 98.43 mm-dia bits, the bit with the cutter smaller than 8.2 mm-dia performed better with respect to the penetration per revolution and the rotational stability at higher speeds of 300 and 400 rpm. Therefore, we fabricated the 142.88 mm-dia bits using the cutters with the diameter below 8.2 mm. The 142.88 mm-dia bits are shown in Figure 3. Details of these bits are described in Table 1 from Nos.6 to 8.

Figure 4 is an example of the results of the tests with the 142.88 mm-dia bits. The penetration of all bits increased with the rotary speed up to 400 rpm in drilling of Sanjome andesite and Shinkomatsu andesite

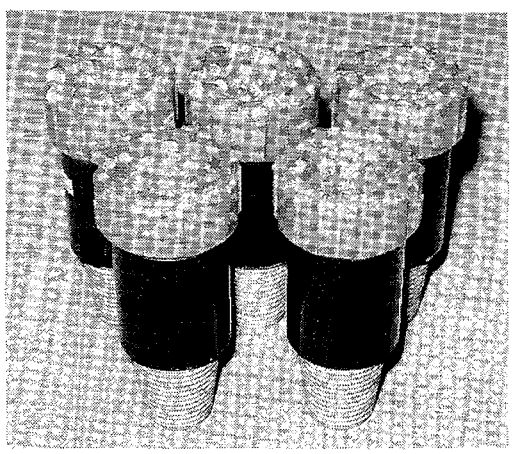

Figure 1 PDC full-face bits of 98.43 mm-dia.

Table 1 Description of PDC full-face bits.

Bit No.	Bit Dia.(mm)	Cutter Dia.(mm)	No. of Cutters	Rake* Angles(deg.)
1	98.43	5.0	48	-10
2	98.43	6.6	36	-10
3	98.43	8.2	29	-10
4	98.43	10.8	22	-10
5	98.43	13.3	18	-10
6	142.88	5.0	100	-10
7	142.88	6.6	75	-10
8	142.88	8.2	61	-10
9	142.88	8.2	67	-10

* Backrake and Siderake

(the uniaxial compressive strength is 118-141 and 145-162 MPa, respectively). On the other hand, the maximum rotary speed of each bit in Sori granite drilling was limited to 256 to 300 rpm, due to the severe bit vibration at speeds of more than 300 rpm. As mentioned before, the penetration rate of the 98.43 mm-dia bits decreased at speeds of 300 and 400 rpm. It seems that the rotary speed should be set below 200 rpm in the case of hard rock drilling such as Sori granite.

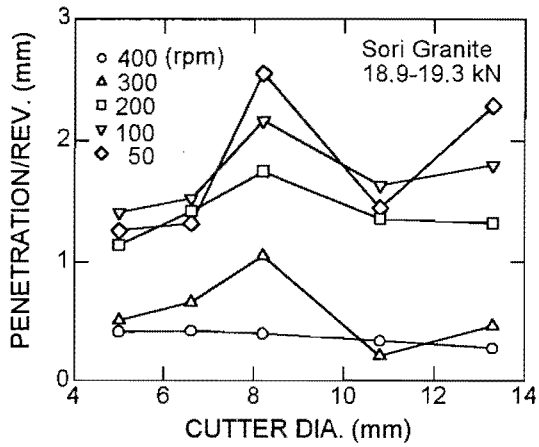

Figure 2 Example of test results (98.43 mm bits).

To understand points for further improvements of the 142.88 mm-dia bits, durability tests with Sori granite were conducted using bit No.7 (Figure 5). During the tests the wear of the cutters increased rapidly, and considerable wear flat on the cutters set around the nose and on the gage were observed after ten meters of granite drilling. From the results of the tests, it became clear that not only the bit design must be improved, but also PDC cutters with improved

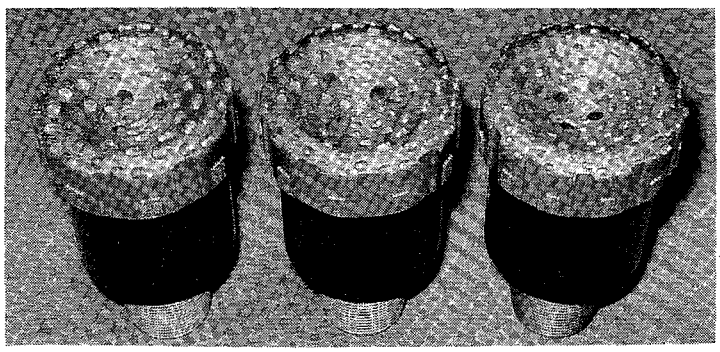

Figure 3 PDC full-face bits of 142.88 mm-dia.

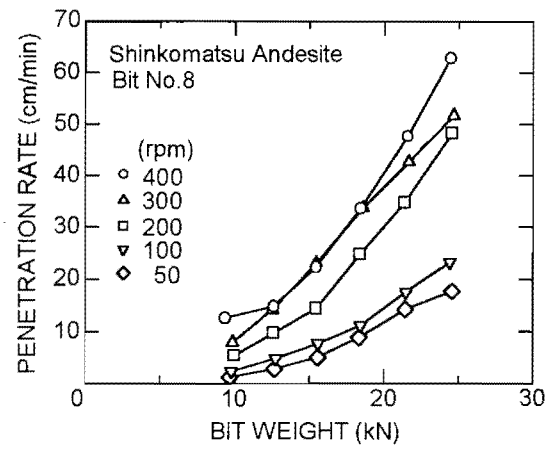

Figure 4 Example of test results (142.88 mm bits).

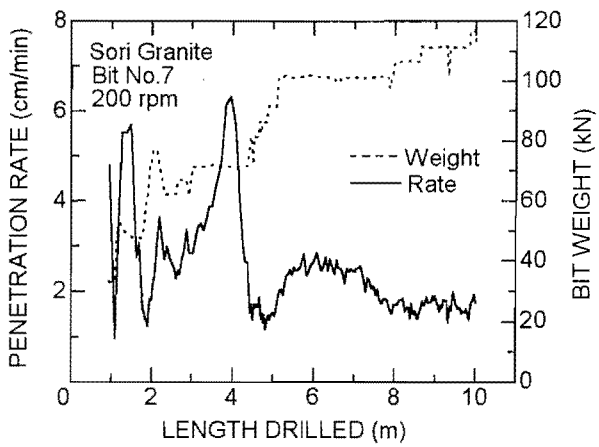

Figure 5 Results of durability tests using bit No.7.

strength is necessary to improve the bit performance significantly for hard rock drilling.

Performance of polished PDC cutter

It is said that polishing of a PDC cutter is one of methods to improve the cutter strength. To understand the performance of the polished PDC cutters, core bits of 66 mm o. d. and 44.8 mm i. d. were fabricated using the polished and conventional PDC cutters (Figure 6). Each bit has eight cutters of 8.2 mm-dia. The durability tests with Sori granite were carried out at a constant rotary speed of 100 rpm. The test results are shown in Figure 7. It is clear that the bit weight of the bit with polished cutters is lower than that of the bit with conventional cutters at the same penetration rate of about 7 cm/min. And, the degree of wear of the bit with polished cutters was smaller as compared to that of the bit with conventional cutters. On the basis of the test results, we selected the polished PDC cutters to improve the performance of the 142.88 mm-dia bits.

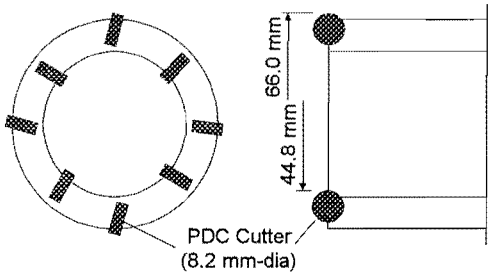

Figure 6 66 mm-dia core bit.

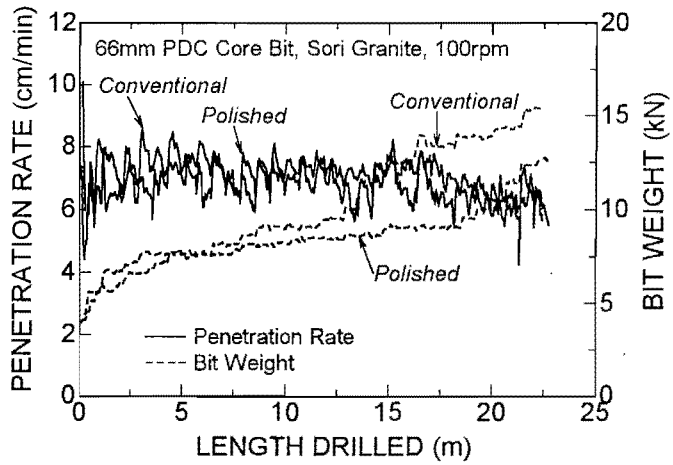

Figure 7 Comparison of the performance between polished and conventional cutters.

Improvement of 142.88 mm-dia bit's performance

Bit No.8 in Table 1 was redesigned and fabricated using the polished cutters of 8.2 mm-dia based on the result of the tests mentioned above. Bit No.9 shown in Table 1 is details of the bit redesigned. The main improvements of this bit are:

- Using polished PDC cutters instead of conventional PDC cutters.
- Increase of additional six cutters set around the nose and rearrangement of cutters.
- Change of the configuration of the bit body (increase of the radius of the nose).

The durability of this bit were also evaluated using Sori granite at the speed of 100 rpm (Figure 8). Bit No.9 reached nearly the bit-life at granite drilling of about 17 m. It is obvious that bit No.9 performed better with respect to the length drilled and the penetration per revolution at the end of testing as compared to bit No.7. After the tests, considerable wear flat on the cutters set around the nose was observed. The performance of the

142.88 mm-dia bit improved, but there is room for improvement with respect to the arrangement of cutters and the number of cutters set on the bit body.

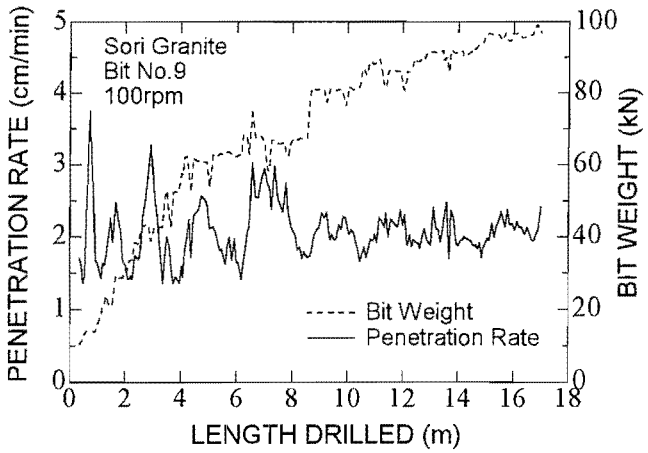

Figure 8 Results of durability tests using bit No.9.

CONCLUSIONS

To develop PDC full-face bits for deep geothermal well drilling, drilling and durability tests were conducted. On the basis of these test results, the 142.88 mm-dia bit (No.9) was redesigned and fabricated using the polished PDC cutters of 8.2 mm-dia. The durability tests revealed that this bit has the bit-life of about 17 m in hard and abrasive granite drilling. In addition, it became clear that the bit must be improved with respect to the arrangement of cutters and the number of cutters set on the bit body in the case of hard rock drilling such as Sori granite.

We are redesigning bit No.9 to increase the bit-life for granite drilling. The number of cutters will be increased from sixty-seven to about ninety and the rearrangement of cutters set on the bit body will be carried out using the design method for core bits such as the 66 mm-dia bits.

REFERENCES

Karasawa, H. and Ohno, T., 1995. "Development of PDC Bits for Downhole Motors", Proc. of the 17th New Zealand Geothermal Workshop, p.145-150.

Karasawa, H., Ohno, T., and Kobayashi, H., 1996. "Improvement of PDC Bit's Performance at High Rotary Speed", GRC Transactions, Vol.20, p.503-508.