**Supplementary material**

**OPTIMIZATION OF HOT-WATER ICE-CORING DRILL**

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**Table *S1*.** Testing results of all drill heads with different flow rates (A – nozzle diameter; B – number of nozzles; C – nozzle angle).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Drill head | Flow rate (L min-1) | | | | | | | | | | | |
| *A* | *B* | *C* | 40 | | | 70 | | | 100 | | |
| ROP\*  (m h-1) | MD\*  (mm) | Core length  (m) | ROP\*  (m h-1) | MD\*  (mm) | Core  length (m) | ROP\*  (m h-1) | MD\*  (mm) | Core length (m) |
| *1* | 1 | 24 | 0 | 12.5 | 63 | 0.41 | 22.7 | 61 | 0.53 | 24.3 | 65 | 0.36 |
| *2* | 1 | 36 | 15 | 6.1 | 82 | 0.68 | 11.2 | 76 | 0.96 | 12.5 | 84 | 0.94 |
| *3* | 1 | 60 | 30 | 2.5 | 81.8 | 0.94 | 3.8 | 74.2 | 0.58 | 5.5 | 73.3 | 0.63 |
| *4* | 1.5 | 24 | 15 | 6.8 | 80 | 0.95 | 6.9 | 63 | 0.61 | 8.4 | 79 | 0.68 |
| *5* | 1.5 | 36 | 30 | 2.8 | 74.2 | 0.48 | 4.2 | 62.5 | 0.50 | 5.7 | 63.3 | 0.51 |
| *6* | 1.5 | 60 | 0 | 7.4 | 60 | 0.65 | 11 | 72 | 0.71 | 18.6 | 57 | 0.65 |
| *7* | 2 | 24 | 30 | 3.2 | 65 | 0.72 | 4 | 69.2 | 0.65 | 4.5 | 71.7 | 0.77 |
| *8* | 2 | 36 | 0 | 7.6 | 58 | 0.82 | 12.5 | 52 | 0.36 | 18.4 | 50 | 0.51 |
| *9* | 2 | 60 | 15 | 7.4 | 79 | 0.73 | 8.1 | 76 | 0.91 | 9.5 | 85 | 0.93 |

\*: ROP – rate of penetration; MD – maximal diameter

**Table *S2*.** The range analysis of three factors with the flow rate of 40 L min-1 (A – nozzle diameter; B – number of nozzles; C – nozzle angle).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Index | ROP\* (m h-1) | | | MD\* (mm) | | | Core length (m) | | |
| *A* | *B* | *C* | *A* | *B* | *C* | *A* | *B* | *C* |
| *‾K1* | 7.03 | 7.50 | 9.17 | 75.60 | 69.33 | 60.33 | 0.68 | 0.69 | 0.63 |
| *‾K2* | 5.67 | 5.50 | 6.77 | 71.39 | 71.39 | 80.33 | 0.69 | 0.66 | 0.79 |
| *‾K3* | 6.07 | 5.77 | 2.83 | 67.33 | 73.61 | 73.67 | 0.76 | 0.77 | 0.71 |
| *R* | 1.36 | 2 | 6.34 | 8.27 | 4.28 | 20 | 0.08 | 0.11 | 0.16 |
| **Ranking** | ***C* > *B* > *A*** | | | ***C* > *A* > *B*** | | | ***C* > *B* > *A*** | | |

\*: ROP – rate of penetration; MD – maximal diameter

**Table *S3*.** The range analysis of three factors with the flow rate of 70 L min-1 (A – nozzle diameter; B – number of nozzles; C – nozzle angle).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Index | ROP\* (m h-1) | | | MD\* (mm) | | | Core length (m) | | |
| *A* | *B* | *C* | *A* | *B* | *C* | *A* | *B* | *C* |
| *‾K1* | 12.57 | 11.20 | 15.40 | 70.39 | 64.39 | 61.67 | 0.689 | 0.596 | 0.533 |
| *‾K2* | 7.37 | 9.30 | 8.73 | 65.83 | 63.50 | 71.67 | 0.608 | 0.608 | 0.827 |
| *‾K3* | 8.20 | 7.63 | 4.00 | 65.72 | 74.06 | 68.61 | 0.639 | 0.732 | 0.576 |
| *R* | 5.2 | 3.57 | 11.4 | 4.67 | 10.56 | 10 | 0.081 | 0.136 | 0.294 |
| **Ranking** | ***C* > *A* > *B*** | | | ***B* > *C* > *A*** | | | ***C* > *B* > *A*** | | |

\*: ROP – rate of penetration; MD – maximal diameter

**Table *S4*.** The range analysis on three factors with the flow rate of 100 L min-1 (A – nozzle diameter; B – number of nozzles; C – nozzle angle).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Index | ROP (m h-1) | | | MD (mm) | | | Core length (m) | | |
| *A* | *B* | *C* | *A* | *B* | *C* | *A* | *B* | *C* |
| *‾K1* | 14.1 | 12.4 | 20.43 | 74.11 | 71.89 | 57.33 | 0.643 | 0.602 | 0.507 |
| *‾K2* | 10.9 | 12.2 | 10.13 | 66.44 | 65.78 | 82.67 | 0.613 | 0.653 | 0.850 |
| *‾K3* | 10.8 | 11.2 | 5.23 | 68.89 | 71.78 | 69.44 | 0.735 | 0.737 | 0.635 |
| *R* | 3.3 | 1.2 | 15.2 | 7.67 | 6.11 | 25.34 | 0.122 | 0.135 | 0.343 |
| **Ranking** | ***C* > *A* > *B*** | | | ***C* > *A* > *B*** | | | ***C* > *B* > *A*** | | |

\*: ROP – rate of penetration; MD – maximal diameter