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STUDYING THE ICE DRILLING PROCESS

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STUDYING THE ICE DRILLING PROCESS

[Article by A. F. Nikolayev and Ye. A. Trubina of the Gor'kiy Polytechnic Institute; Moscow, Rybnoye Khoziaistvo, Russian, No 6, June 1969, pp 52-53]

The first lot of PRAG-GPI-56 ice drills for mechanizing ice fishing was fabricated in 1968.

Selecting the cutting tool -- the bit, substantiating its geometry, and determining the dynamic properties of the drilling process were the most complicated questions concerning the operational reliability of these ice drills, which were developed by Gor'kiy Polytechnic Institute. Unfortunately, not all of these important questions have been studied properly yet.

In order to clarify the interrelationships of basic drill rig parameters with the drilling regime, studies were made of torque, axial feed load (osevoye usiliye podachi), drilling speed, and number of drill revolutions. In order to determing the qualitative and quantitative dependence of feed load and torque on the diameter of the working member and its feed per revolution, experiments were conducted with cyclic and continuous drilling and with two types of bits: with lobed (lopastnyy) tips (Ø175, 250, and 350 millimeters), and with flat (perevoy) tips (Ø110, 175, and 250 millimeters).

The number of drill revolutions per minute was varied from 102 to 1,040. Penetration speed was 1.03-4.24 millimeters per minute. Feed per bit revolution for all bits was varied from 15.4 to 2.65 millimeters per revolution.

All the tests were conducted on lake ice and Volga ice.

Two series of tests were conducted for each form and type of bit: the first series established the dependence of the feed load P_o and torque M_{kr} on bit diameter D (figures 1

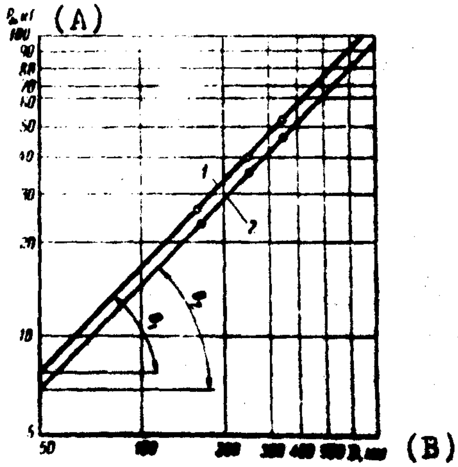

Figure 1. Dependence of feed load on drill diameter ($tg\theta_1$ = 1.02; $tg\theta_2$ = 0.99 at ice temperatures:
1 -- 8-10 degrees below 0 C.
2 -- 0-3 degrees below 0 C.

Key:
(A) P_d [sic], kgf
(B) Diameter, millimeters

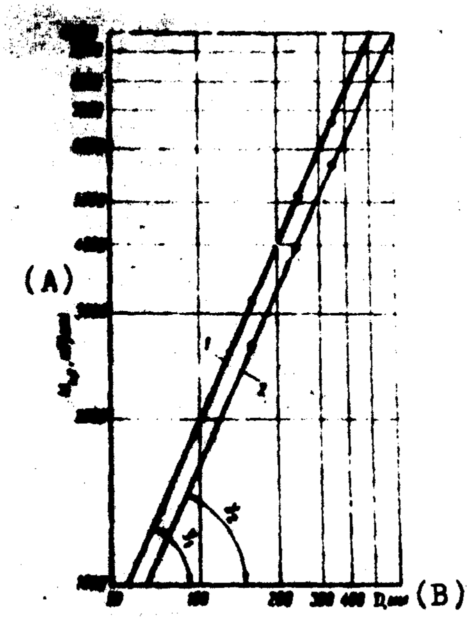

Figure 2. Dependence of torque on drill diameter ($tg\gamma_1 = z_{m1}$ = 2.1; $tg\gamma_2 = z_{m2}$ = 2) at the same ice temperatures.

Key:
(A) M_{kr}, kgf/mm
(B) Diameter, millimeters

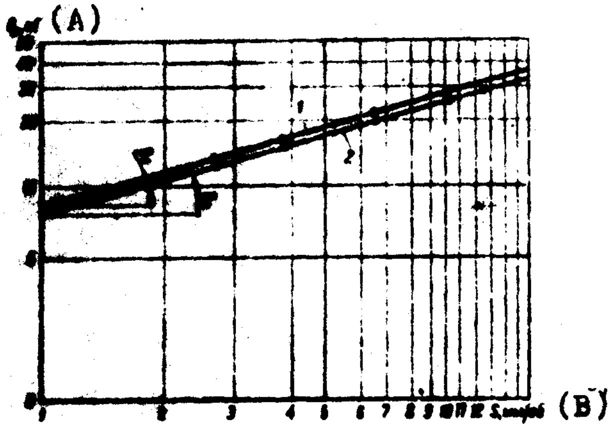

Figure 3. Dependence of feed load on speed of conveyance ($tg\beta_1$ = 0.28; $tg\beta_2$ = 0.27) at the same ice temperatures.

Key:
(A) P_o, kgf
(B) S, millimeters per revolution

and 2). Conveying speeds were identical, 15.4 millimeters per revolution. The second series established the dependence of the feed load and torque on the amount of feed S (figure 3). In so doing, bit diameter was constant, 250 millimeters. Analytical-tabular processing of the research data established the fact that the consistency in change of feed load and torque with bit diameter and amount of feed was identical for all the bits studied. This is demonstrated in double logarithmic coordinates by a family of straight lines, the tangent of whose angles of inclination indicates the nature of the change. Feed load and torque increase as drill diameter and feed increase, the diameter having a greater influence than the feed.

This relationship can be described analytically with the following empirical equations (similar to analogical equations for drilling metals and other materials):

$$P_o = C_r D^{z_r} S^{y_r} \quad \text{kilograms (force)}$$

$$M_{kr} = C_m D^{z_m} S^{y_m} \quad \text{kilograms (force)·millimeters}$$

where C_r and C_m are coefficients which are determined analytically when the test data is processed and which describe the worked material (the medium), the geometry of the cutting part of the drill, and other operating conditions; and

z_r, z_m, y_r, and y_m are exponents for the diameter and feed values, which describe the laws by which P_o and M_{kr} change with D and S, and which are defined as the tangents of the angles of inclination of the straight lines constructed from the test data.

The following formulas were obtained, based on the experiments, for describing the feed load and torque when drilling ice whose temperature averaged 8-10 degrees below 0 C.:

$$P_o = 1.43D^{1.02}S^{0.28} \quad \text{kilograms (force)}$$

$$M_{kr} = 0.49D^{2.1}S^{0.39} \quad \text{kilograms (force)·millimeters}$$

and when drilling ice whose temperatures average 0 to 3 degrees below zero C.:

$$P_o = 1.34D^{0.99}S^{0.27} \quad \text{kilograms (force)}$$

$$M_{kr} = 0.63\ D^2S^{0.31} \text{ kilograms (force)}\cdot\text{millimeters}$$

The values for P_o and M_{kr} were 45 percent greater for flat tips under the same conditions.

Processing of data on the continuous-method drilling indicated that the feed load and torque were increased as drilling depth increased.

In the general case the axial force acting on the drill during continuous drilling was equal to:

$$P_o = P_{pr} + P_{b.i} + P_{v.i} \text{ kilograms (force)},$$

where P_{pr} is the coercive (prinuditel'nyy) axial force created by the drill rig;

$P_{b.i}$ is the axial force created by the drilling tool; and

$P_{v.i}$ is the force from the weight of the tool.

The axial force component from the interaction of the ice chips with the worm conveyer can be determined by bit depth according to the relationship proposed by S. I. Bril and Ye. M. Gut'yar for soil:

$$G' = G_s \cdot \frac{tg\,\xi}{\epsilon\, tg\alpha},$$

where G_s is the weight of the ice chips in the hole;

α is the angle of elevation of the worm conveyer screw surface;

ϵ is the coefficient of slippage of ice chips along the worm conveyer; and

ξ is the angle between the direction of the drift speed of the worm conveyer point and a horizontal line.

Under the influence of the drill the chips are drawn into a rotary motion, the force of inertia of the rotating chip particles emerges, and, interacting with the walls of the hole, gives rise to additional axial force.

The additional axial force from interaction of the ice chips on the worm conveyer with the wall of the hole is equal to:

$$G'' = G_s \omega^2 \frac{r_\ell^2 - r_{s.b}^2}{8g} \epsilon f_2 \frac{tg\xi}{tg\alpha},$$

where ω is the angular speed of the drill;

r_ℓ is the radius of the hole;

$r_{s.b}$ is the radius of the drill rod;

g is the acceleration of the force of gravity; and

f_2 is the coefficient of the friction of the ice with the ice.

Thus, the total axial force acting on the working member during drilling is:

$$P_o = P_{pr} + P_{b.i} + P_{v.i} + G_s \omega^2 \frac{r_\ell^2 - r_{s.b}^2}{8g} \epsilon f_2 \frac{tg\xi}{tg\alpha} .$$

Total torque on the drill shaft is:

$$\Sigma M = M_p + M_r + M_t,$$

where M_p, M_r, and M_t are the torques expended, respectively, on overcoming the drag of the drill bit, and resistance to the cutters and to the transport of ice chips by the drill.

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In order to clarify the interrelationships of basic drill rig parameters with the drilling regime, studies were made of torque, axial feed load, drilling speed, and a number of drill revolutions. In order to determine the qualitative and quantitative dependence of feed load and torque on the diameter of the working member and its feed per revolution, experiments were conducted with cyclic and continuous drilling and with two types of bits: with lobed tips & flat tips. The number of drill revolutions, penetration speed and feed per bit revolution were varied for each test, with two series of tests conducted for each form and type of bit. All tests were conducted on lake ice and Volga ice.

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