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BZXJ SUPER LIGHT ICE CORE DRILL

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Abstract: An advanced BZXJ drill was developed and named after key Chinese characters which mean an electro-mechanical ice core drill. Its main advantages are: light weight, low power consumption and convenient installation. The drill has the merits of both an electro-mechanical Japanese ice core drill and an American SIPRE/CRREL 3 inch auger. Its major characteristics are: 160 cm length, 11 kg of weight, about 50 rpm core barrel rotation speed, about 35 cm length core section extracted during one run, 0.3 kW power consumption, 150 m depth capabilities. The total weight of drilling system is 127 kg. The drill can be set up and operated by two specialists.

A few glaciers have been drilled to bedrock in China by BZXJ. Also about 700 m total length of ice core have been obtained from the Collins Ice Cap, King George Island, Antarctica. Where the maximum depth of 80 m borehole have been drilled. It was shown on high mountain glaciers that the BZXJ is suitable for firn and ice coring.

1. Introduction

Abundant paleoclimatic and environmental information is stored in polar, middle and low latitude glaciers (OESCHGER and LANGWAY, 1989). In order to obtain those precious ice or firn samples, great effort has been put into deep core drilling technology development. Development of a light weight, high efficient drill for coring to the 100 m depth range interval is a special technical challenge. Difficult transportation and harsh working conditions on high elevation glaciers especially calls for light weight, portability and low power consumption coring instruments. The BZXJ super light ice core drill was developed to meet all above requirements.

The drill is named after the abbreviation of key Chinese characters for an electro-mechanical ice core drill. It was developed on the operating principle of a Japanese double barrel drill (SUZUKI, 1984) and the American SIPRE/CRREL 3 inch core auger (RAND and MELLOR, 1985). The drilling system (Fig. 1) is capable of coring up to 150 m depth. It has four components: (1) cable suspended drill, (2) electrical winch equipped with mast and steel armored electrical cable, (3) control panel, and (4) gasoline 2 kW electrical generator.

2. Drill Structure

The SIPRE/CRREL auger system provides good quality ice core up to 50 m depth. The structure of the drill is simple. That is why it was applied to coring over glaciers, sea, lake ice and permafrost conditions. However, the system cannot be useful for drilling deeper than 50 m. For the purpose of shallow drilling (depth about 100 m) on glaciers several electro-mechanical cable suspended drills have been developed (RAND, 1976; RUFLI *et al.*, 1976; JOHNSEN *et al.*, 1980; GILLET *et al.*, 1984). Some of above systems are capable

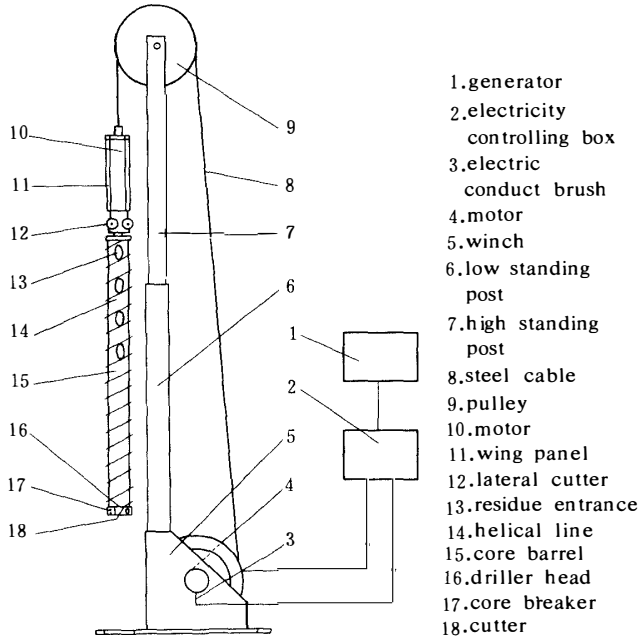

Fig. 1. Schematic of the BZXJ drilling system.

for dry hole coring up to depth of 350 m. Most portable shallow coring systems have been developed by Y. SUZUKI (SUZUKI and SHIMBORI, 1984). These shallow drills use a double wall core barrel, rotated by an electrical motor. The cuttings from the borehole bottom are retrieved by the helical flights mounted on outer surface of the inner core barrel. The weight of these drills exceed 40 kg while the power requirement is close to 0.5 kW or higher.

To combine advantages of the hand auger and shallow cable suspended drills the BZXJ drill was developed. Major technical characteristics of the BZXJ drill presented in Table 1. This drill does not have an outer core barrel. The chips are conveyed by flights between the barrel and borehole wall. There is a decrease in the kerf width and chips volume respectively. The cuttings stored in the core barrel above the core and are removed from the hole every drilling run. Drill power is provided by a 0.3 kW AC motor. The antitorque system is similar to JARE electro-mechanical drill (SUZUKI and SHIMBORI, 1984).

Table 1. Technical indexes and efficiency of cutting of the SIPRE/CRREL and BZXJ drills.

Drill	Borehole/core diameter, mm	Cutters width, mm	Efficiency of cutting
SIPRE/CRREL	111/76	17.5	1.13
BZXJ	91/65-67	13	0.98

Core barrel (Fig. 2): The core barrel is composed of a 76 mm diameter stainless steel tube with a 2 mm thick wall. A smooth grade 7 finish made it favorable for the passage of chips. During coring stainless steel 3 mm width and 5 mm height helical lines (set of 3)

drive the chips upward. Resistance for cuttings transport was reduced dramatically owing to careful and accurate machining and welding. To raise the efficiency of chip transport, the distance between helical lines has been reduced compared with other shallow drills. The pitch of the flights is 194 mm. It corresponds to 39° of helical angle. The chips entrances were arranged on the upper part of the barrel close to the helical lines. A total of 12 elliptical windows are uniformly distributed in 4 vertical rows.

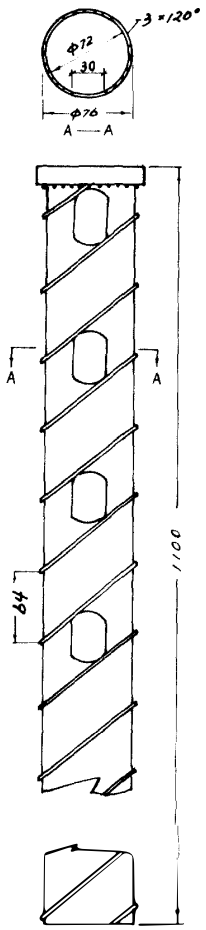

Fig. 2. Structure of the core barrel.

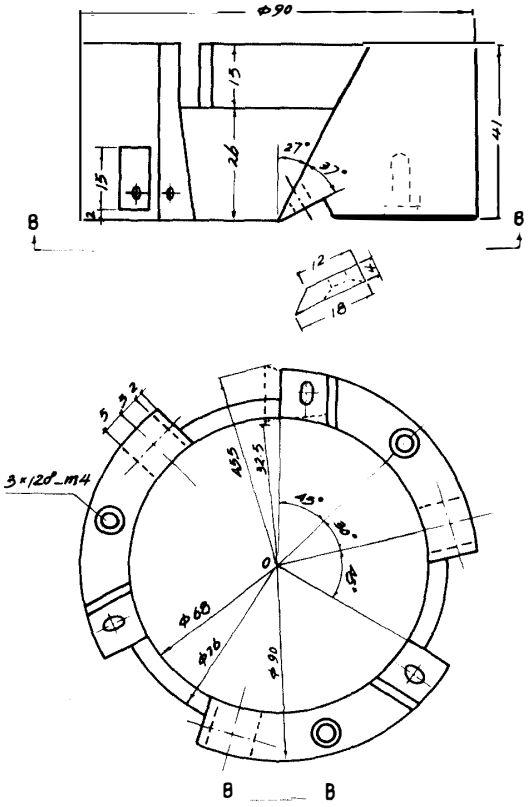

Fig. 3. Structure of the drilling head.

Drilling head (Fig. 3): The drilling head is equipped with three straight cutting edge blades and three core catchers (not shown in Fig. 3). It was found that 13 mm width cutters provide smooth penetration and good quality ice core. To estimate the efficiency of cutting, the ratio of ice chip to core volume has been used. The smaller the ratio, the greater efficiency of drilling. Data presented in Table 2 suggest that the present structure and dimensions of the core barrel and drilling head assembly under optimal drilling regimes provide effective cutting. That chip to core volume ratio of the of SIPRE/CRREL drill is higher than that of BZXJ drill.

To reduce cutting resistance and increase the speed of penetration sharp cutters with a small blade angle should be used. However, the bending strength of a flat blade is badly reduced when mounted at small angle. Therefore, the optimal angle of 37° has been

Table 2. Optimal power of the BZXL drill.

Glacier material density, kg/m³	Voltage (V)	Current (A)
500–700	110	0.8-1.0
700–830	120	1.0-1.2
>830	130	1.1-1.3

chosen. The light weight drill is more efficient with small rake angle. The pitch of cutting can be adjusted by special screws located at the bottom end of drilling head. For fast penetration and obtaining good quality ice core the mutual coordination of suitable cutting depth and rotation speed of the drilling head should be achieved. It was found that the BZXJ drill has its best performance at a rotation speed of 30–50 rpm and 0.3 mm cutting pitch.

During penetration, cutters carved a 0.5 mm depth spiral on the core and borehole surface. It was found experimentally that such crude surfaces assist chips removal. Also, rough surface of the core was beneficial for breaking the core. The core catching efficiency of the BZXJ was as high as 95%.

Antitorque system: To perform penetration by drag cutters, the cable suspended drills should have a torque reaction. In BZXJ the principle of the borehole wall side groove antitorque system was adopted from JARE drill (SUZUKI, 1984). The prototype antitorque system has four lateral cutters which create vertical grooves along the borehole wall. To produce a torque reaction, four skates follow the grooves. Operation of the prototype antitorque system provides extra downward force on drill. Therefore, operation of the antitorque system has an effect on the cutting process. In BZXJ drill, the direction of rotation of the side cutters is opposite to the prototype system. After this change in rotation of the cutters maintenance of a vertical hole was improved.

Major technical characteristics of the BZXJ drilling system

Cable suspended BZXJ drill has a following characteristics:

weight	11 kg
length drill/core	160/35 cm
diameter hole/core	91/67 MM
power (motor)	0.37 W; (220 VAC, 1.7 A)
rotation speed	50 rpm
feeding speed	8–10 mm/s

The winch has the following major parts: (1) 2.5 m height mast, (2) 250 m long steel armored cable, (3) 1 kg weight control box, and (4) 300 W electric motor, which provide 25 m/min of drill raising speed and 60 kg of pulling force. The total weight of the winch assembly is about 70 kg.

The system includes a 2 kW gasoline electric generator of 45 kg weight.

3. Coring Practice

The BZXJ drill was developed in 1989 and has been used on a few glaciological expeditions. It drilled to the bedrock on the following glaciers in China:

• the No. 1 Glacier at the headwater of Urumqi River, Tianshan (4050 m a.s.l.). In November 1990 a borehole of about 90 m depth was drilled.

• the No. 7 (Nakeduola) Glacier at Xixiabangma range (6000 m a.s.l.). In September 1991 about 40 m deep hole was bored.

• the Chongce Ice Cap at West Kunlun Mountains (6530 m a.s.l.). In October 1992 a 52 m long core was recovered.

In Antarctica (King George Island), from November 1991 to October 1992 a total length of 700 m ice cores has been obtained on Collins Ice Cap with aid of the BZXJ drill. Maximum coring depth was 80 m.

Performance tests of BZXJ drill have been carried out on the No. 1 Glacier. Results of penetration performance are shown in Fig. 4. It could be estimated from the curves in Fig. 4 that for 50 and 90 m depth coring takes only 10 and 29 working hours respectively. The drilling on Collins Ice Cap showed that four specialists needed only 7–10 hours for coring of snow and firn to depth of 40–50 m. That time included the core logging and packing.

To obtain a good quality core the optimal drilling procedure have been found experimentally. Depending on glacier material density, optimal drill motor voltage and current are shown in Table 2. The operation of the drill in the field is very simple. Using the penetration screws on the drilling head, the operator matches material density and the drill motor current. During one run the drill recovers about 35 cm long segment of the core. However, the complete penetration depth during one run is about 70 cm. It means that drill penetrate 35 cm thick layer of chips at the hole bottom. The total preparation time for every drilling run is about 1 minute.

A few times during above drilling operations the BZXJ drill have been stocked and successfully removed from the holes. Catastrophic failures such as damage of the drill mechanism has not happened so far.

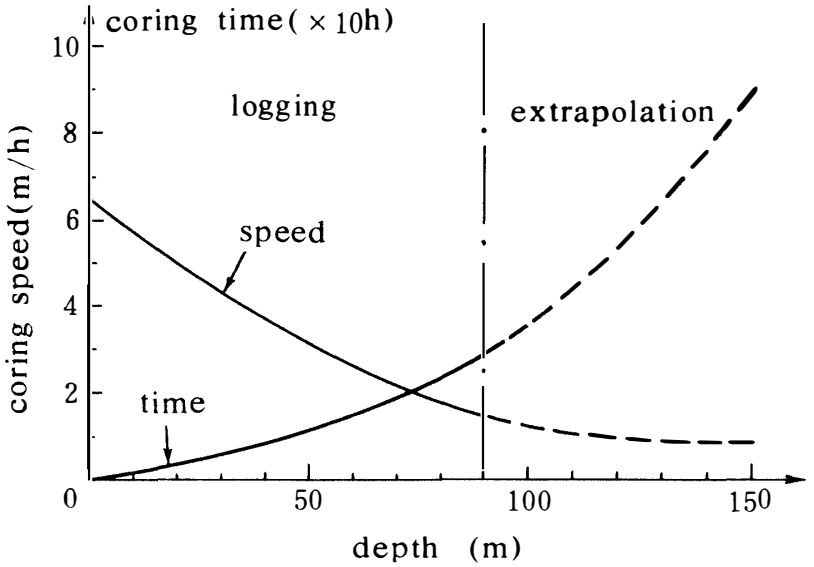

Fig. 4. Penetration performance of the BZXJ drilling system.

4. Conclusions

The data suggest that the BZXJ drill is a useful super light coring instrument suitable for routine glaciological investigations in high mountain glaciers. The efficiency of the drill can be increased by using a longer barrel and narrow cutters.

Acknowledgments

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