REFINEMENTS OF THE UCPH SHALLOW DRILL

by

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ABSTRACT

In the period 1975 to 1978, UCPH developed their version of the Rand/Rufli shallow drill. The primary objectives of the drill were : ease of handling, light weight and fast site preparation. In order to realize the primary goals, core length is restricted to 90 cm in solid ice.

Based on experience gained from the UCPH deep drill (ISTUK), the shallow drill was modified to enhance the primary goals, that remained unchanged. The modifications included new cutters, introduction of a pitch controlling shoe, introduction of core catchers and improvements to the slip ring assembly in the winch. The modifications have reduced the drill power to 160 W at 70 m depth and 300 W at 300 m depth. The low power used by the drill has enabled it to recover cores at depths exceeding 300 m. Following the same basic layout, a hand auger has been developed.

INTRODUCTION

Based upon original designs from the SIPRE hand auger, the Icelandic drill (Arnason and others, 1974), the Swiss shallow drill (Rufli and others, 1976) and the US, CRREL shallow drill (Rand, 1976), the first version of the danish shallow drill was developed in the time period 1976 to 78 (Johnsen and others, 1980). The drill uses a leaf spring antitorque system, and as something new, a tiltable tower, just 2.3 m high. Using a tiltable tower, the usual pit used while separating the inner core barrel and the core from the rest of the drill has been replaced with a small incline trench 1.2 m deep, 30 cm wide and 1 m long. In operation, the drill is often used mounted on a "Nansen sledge". This cuts the setup time down to a minimum, and allows several 25 m cores to be retrieved in one day.

The development of the deep drill (ISTUK) led to a better understanding of the cutting process and the handling procedures. Several of the techniques from the deep drill is of general nature, and has been introduced in the shallow drill.

DESCRIPTION

The slip rings in the winch has been improved. Originally, the connections were made with commutator graphite. Dust from the graphite at times created leakage between the rings. Pure metal connections would create a risk of introducing wear on the rings, so the problem was solved with contacts made of 90 % silver and 10 % graphite.

The **cable** is the same steel armored 5.6 mm as purchased in 1976. Although the cable now shows some sign of age, we expect to use the old cable for yet another 12 years. The cable is light weight (12.3 kg/100 m), and the steel cables low elasticity is a prerequisite for operating the hammer in the drill.

The **antitorque section** is also unchanged from the description in Johnsen and others (1980). The antitorque is produced by three 2 mm thick, 20 mm wide and 500 mm long leaf springs. As the torque required is low, the antitorque system never fails, even while drilling in ice with ice layers or loose snow. The flexibility of the springs adjusts to the properties of the snow. The design of the springs is described by Reeh (1984).

The **motor** is the same double Mavilor disc motor. The low power needed after improving the drill head means, that we are using the same double motor for now 12 years. The motor rating is 5 amps nominal, and the maximum current experienced is 3.5 A at a depth exceeding 300 m. The gear is also not changed. The 80:1 reduction "Harmonic Drive" has just been replaced once, while the motor section was used for something else. The motor shaft and the bearing that transmits the cable force to the inner core barrel have been redesigned. The new design is simpler, making use of a more advanced bearing. Drawings are available on request.

The **inner** and **outer core barrel** are also unchanged. The stainless barrels are light and clean, and we see no reason to change. The surface of the inner core barrel is polished. The chips transport between the barrels is maintained by fine grooves on the inner side of the outer barrel. This system works without problem as long as the chips are reasonable coarse, and we have seen no reason to change to the more familiar strips fixed to the outer core barrel. The **auger flights** on the inner core barrel has been replaced with Polyethylene High Density (PEHD) flights, screwed to the inner core barrel. The material has been chosen after advice from B. Koci and H. Rufli, and it has served well for now 5 years in ice temperatures to -32°C. The flights are cut as a spiral from a PEHD tube, boiled in water for an hour, and then quickly clamped in place. Treated this way, the PEHD keeps the new shape. After the spiral is screwed to the barrel, it is turned in a lathe to a diameter that makes the barrel turn in the outer barrel with minimum friction and clearance.

The **electronics** are still the 12 year old SCR control. The main draw back of this control is, that it is relatively open, making snow penetrate the enclosure while drilling : For drilling up to 100 m, the operation normally uses no tent. All equipment is placed directly on the surface without cover. Snow in the control has led to some breakdowns, but as it is easy and cheap to change the SCR regulators, we have not yet build another regulator.

DRILL HEAD

The key changes are made to the drill head. The ISTUK experience showed, that the drill head is probable <u>the</u> most critical item in the drill. Although this drill was operating in a liquid at great depths, we considered the following experience as general :

1 - Use very sharp cutters.

2 - Create a relief angle after **all** cutting edges - also the side of the cutter.

3 - Use aggressive cutters - they produce coarse cuttings that are easily transported by the flight augers.

4 - Make sure, that the drill head is very stable.

5 - Use a rake angle of 45° and a relief angle of 12°.

6 - Control the pitch with a shoe as used in a plane.

7 - Use the a slightly smaller rake angle for the core catchers.

8 - Use a double spring system on the core dogs, keeping them in upright position while not engaged.

9 - Place the core dogs as far down as possible.

10 - Have close tolerance between bottom of drill head and core preventing chips to wedge in between drill head and core.

11 - Keep open space around the core dogs allowing chips the maximum volume.

12 - Clean the drill with a brush and pressurized air. Do not use any solvent.

Figure 1 shows the modified drill head based on these rules. The head is seen from above with part of the head around the core dog cut away in order to expose the core catcher. The core dog turns around a steel pin, and a small screw prevent the pin from falling out. The core dog is pushed against the core by a V-shaped steel wire spring. The head is made of ordinary stainless steel. The surface is polished to enhance chip flow and to minimize the risk of the ice chips to stick to the head. The head is replaceable. It is fixed with 3 screws near the upper rim of the head.

A key point is that the cutters do not determine the penetration rate : The cutters are so aggressive, that they tend to dig themselves down in the ice. This means, that no cutter load is needed, and while drilling the operator controls the winch to keep the cutter load to a minimum. Using very little load on the cutters, and keeping the major part of the weight of the drill in the cable, the drill hole can be nearly vertical. In the deep drill, deeper down in the ice, the cutter load used was negative : we pulled upward the drill after the bits engaged. In the shallow drill, using negative cutter load has not been possible. The reason is probably, that the ice at the bits fractures. In the liquid filled hole, the pressure release is separated from the cutting process. This produces better core quality and a cutting process that dig the bit down in the ice with great force.

The penetration rate (pitch) is determined by shoes mounted on the bits 1 cm after the cutting edge. In Figure 2, that shows the drill head as seen from below, the shoes are clearly visible. Their width are somewhat smaller than the bits, making sure that the side of the shoe gives minimal friction. Note the small hole in the head below the center of the core catchers. One end of the small spring, that keep the core dog in upright position while not engaged, goes down in this hole.

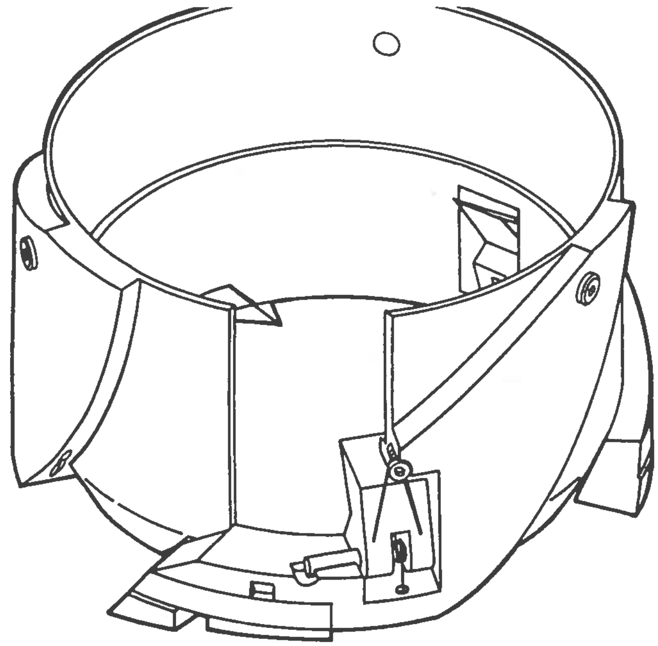

Figure 1 - Drill head used in shallow drill and hand auger as seen from above. Part of the head is cut away to expose the core catcher and its spring. The head is screwed to the inner core barrel with 3 screws. The material is stainless steel for the head, and tool steel for the bits.

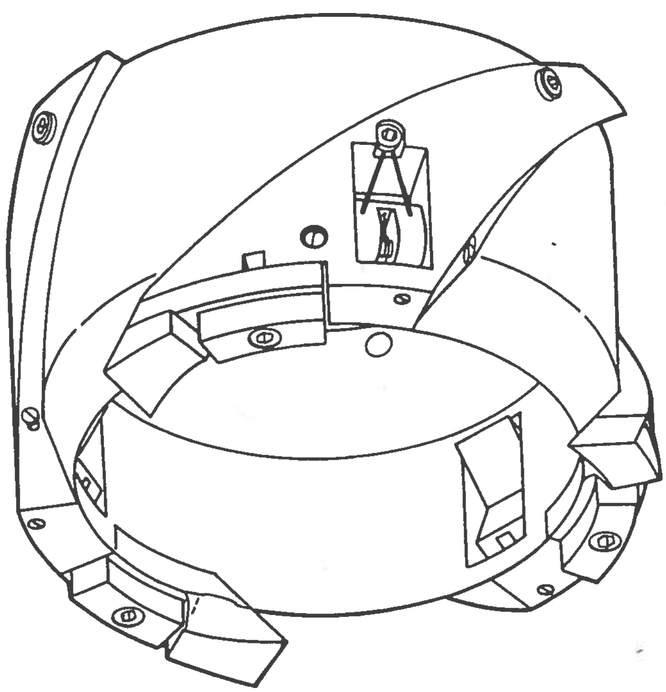

Figure 2 - Drill head as seen from below. On the inner surface, one corecatcher penetrates into the space for the ice core. Note, that the core catcher when not engaged do not fall down - a small soft spring between the core dog and the drill head prevents the dog to fall down. Also seen is the shoes mounted on the bits, after the cutting edge. The size of the shoe allow the handauger to start from the surface even in loose snow. The bits can be removed pushing a tool into a grove in the head.

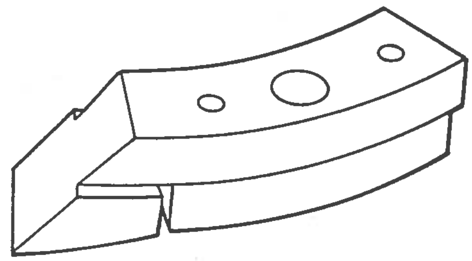

Figure 3 - Bits seen from above. The rake angle (the angle between vertical and the front plane of the cutter is 45°, the clearance angle is 12°. The bits are positioned with two pins, and held in place with a single screw.

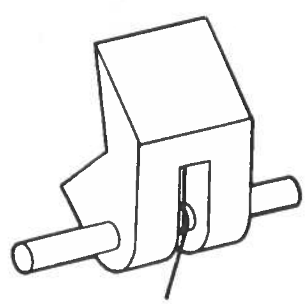

Figure 4 - Core catcher. The core catcher are pushed against the ice core with a small strong V-shaped wire spring. The catcher is prevented from falling into the head when not engaged using a soft spring placed in a grove in the catcher.

The bits, that are replaceable, are shown in figure 3. The bits are made of ordinary tool steel. The rake angle is 45 deg, the relief angle 12 deg leaving a 33 deg wedge of steel. The cutting angles are sharpened very carefully, trying to keep the edges sharp as a "swiss army knife". Also the sides of the cutters are sharpened with a relief angle behind the front edge. As the cutting process in a shallow drill is not quite as critical as in the deep drill, the relief angle at the side of the cutter do not start at the front face, but 0.5 mm behind. Thus, the cutters can be sharpened without changing hole diameter. This works very efficiently - we have used the same set of cutters for many years. The cutters are fastened to the drill head with a single screw, and kept in place with two pins. The shoes are mounted on the cutters.

Figure 4 shows the core catcher. Note, that the core catcher is kept in upright position while not engaged by a small spring placed at the center of the tool. This spring has been introduced after experience with the deep drill : At times, we had core breaks leaving a slanted surface. With core catchers in horizontal position, they would turn into the side of the slanted top of the core when the drill started to rotate in the next run. The skew side of the ice core would then break reducing core quality and with a high probability of a lost run.

Figure 5 shows the core catcher in upright and engaged position. The diameter of the ice core is 78 mm, and the diameter of the hole 104 mm. The clearance between the lower part of the drill head and the core is 0.5 mm, the clearance between the inner core barrel and the ice core is 1.0 mm. The wedge angle of the core catcher is 30°, the rake angle is reduced from the 45° used for the bits to 35° making the core catchers less aggressive. But again, the core catchers are as sharp as possible.

HAND AUGER

A hand auger has been constructed using the same components as the shallow drill. The drill head is the same, the dimensions of the core barrel are unchanged except for the length that is reduced to 1.2 m. The handle, rods and clamp between rods and core barrel are the same as used in the swiss hand auger (Rufli, private communication), and are commercially available in Switzerland. Thus, the core diameter is the same as for the shallow drill, simplifying logging and storage of ice cores. The hand auger is normally used for drilling cores of 12 m length. If deeper cores are needed, the shallow drill is used as it can recover several 25 m cores in one day.

CONCLUSION

During its twelve years of service, the danish shallow drill has just undergone few changes. The key changes are the use of aggressive cutters and the use of pitch controlling shoes. This has reduced the power consumption to around 200W, and made it possible to drill a vertical hole.

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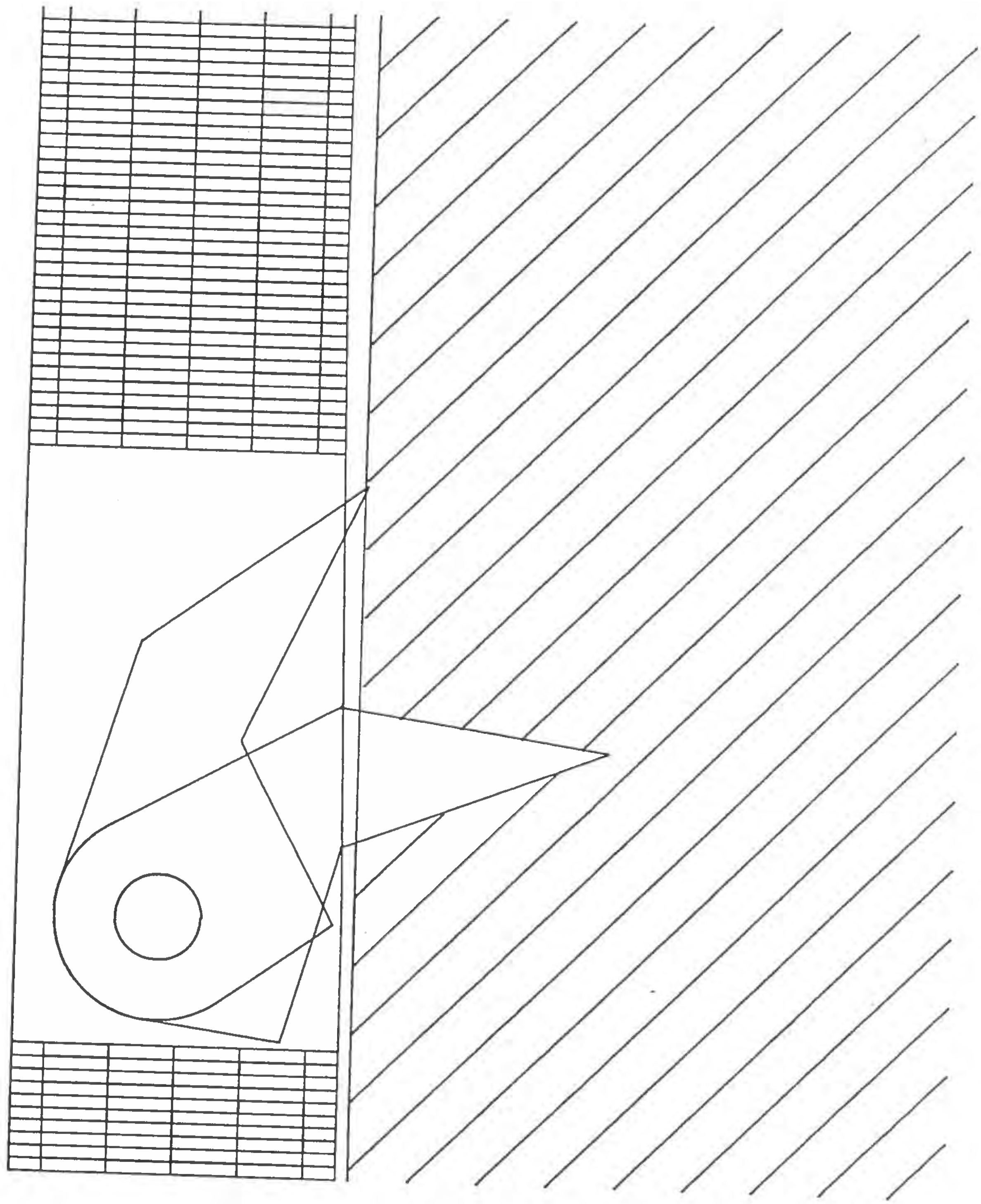

Figure 5 - View of core catcher in normal and engaged position. The distance between ice core and lower part of drill is .5 mm, between inner barrel and ice core 1 mm. The clearance between drill head (or outer core barrel) and hole wall is 1.2 mm.