NEW HORIZONS IN DRILL DEVELOPMENT

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Abstract

New materials for cables and cutters are discussed in relation to lightweight and efficiency. Kevlar, used as the strength member in an electromechanical cable, reduces weight by 70 percent and allows the use of smaller diameter sheaves and winches. Efficient cutters and core breakers are discussed along with a selection of materials suitable for drilling in cold ice. Use of small diameter hermetically-sealed heaters in a ring are also discussed to complete this 200 m system which can be backpacked into remote areas. This drill can take 7.6-cm or 10-cm diameter cores in lengths varying from 1- to 2-m. The approximate weight of the system is 400 kg and the cube is 1.2 m^3 with minor variations depending on which drill is chosen.

Introduction

Recent developments in materials and power sources have increased depth capability of electromechanical drills while reducing the weight and power requirements. Materials developments include Kevlar reinforced cables and steels for cutters that are hard without being brittle at low temperatures. This design flexibility has made it possible for PICO to develop a 200 m drill that can be run on solar power and which can be backpacked into remote areas.

Materials and Power Sources

The importance of drill bit design and core dog shape is critical in lightweight drill design. Refinements in drill bits have reduced power requirements to the 400 watt range, allowing the use of torquing motors and eliminating the requirement for a gear reducer. As a result, weight is removed from the upper end of the drill, making the system more stable. Currently, the motors have a torque capacity of 22 N-m at 180 rpm. Each motor weighs approximately 4 kg. Selection of a proper core dog shape is critical to keep the winch, cable and tower compact and light. Core breaks in ice at South Pole Station during the 1981-82 season were reduced from 3000 kg to 250 kg by the use of newly-designed core dogs (Figures 1a and 1b).

Optimum core dog design is similar to proper bit design in that a minimum amount of energy is desirable to cause fracture. Generally the bisector of the point angle should enter the core at an angle of 30°. If the included angle of the point is chosen as 30°, then any upward force is multiplied by two. Additionally keeping the point very sharp can cause a stress concentration factor of 3. When the core dogs are working properly, the bottom of the core should have a slightly concave shape since the initial fracture will start with an upward component. Selection of rounded surfaces make the core dogs penetrate more easily than flat surfaces based on our field tests.

Material selection for core dogs is not critical as long as the points are kept sharp. Use of stainless because of its resistance to embrittlement in cold (T < -20°C) is suggested for the core dog pin.

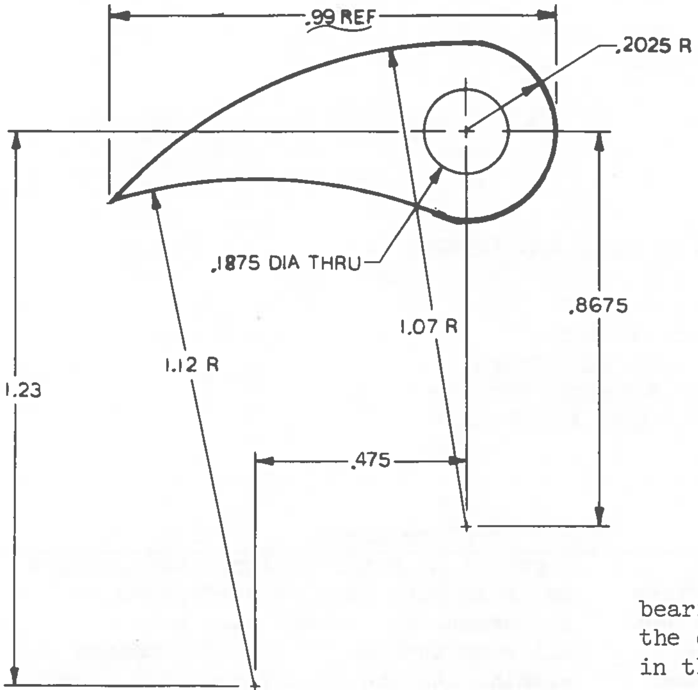

Figure 1a. Core dog

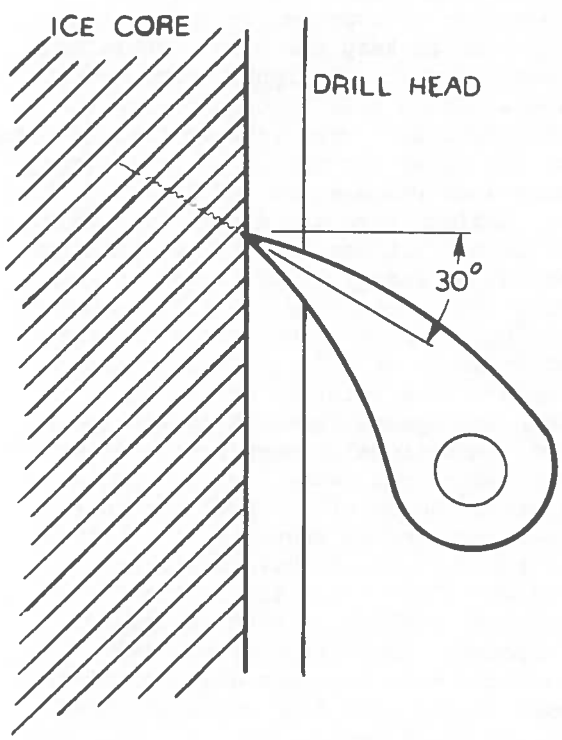

Figure 1b. Core dog position relative to ice core

Proper materials selection for cutters is essential. The presence of carbon in most tool steel causes brittleness as the temperature drops below -20°C. Maraging steels, 440 stainless alloys, and high cobalt tungsten carbide alloys show promise in providing hardness and toughness. Evaluation of these materials in -52°C ice at South Pole was completed this past season. A-2 tool steel was found to be the best of available tool steels since it did not chip as readily as the high speed steels. The 440 C stainless and maraging grade of steels were slightly better in resistance to chipping and could generally be kept sharper. The 25 percent increase in materials and machining costs thus becomes questionable.

The hard but brittle nature of cold ice suggests a need for self-centering bits that provide bearing surfaces to keep from shattering the core. Round cutters are superior in this respect but require a higher bit pressure to penetrate increasing the likelihood of drilling a crooked hole. A more promising design is suggested in Figure 2. Note the lead angle has been increased from 45° to 50° for -50°C ice suggesting an increase in clearance angle from 10° to 15° to maintain a "fine" wedge shape.

A key element in this package is the Kevlar reinforced electromechanical cable. This cable with 7 #20 conductors and 3000 kg breaking strength weighs about 13.2 kg/100 m compared to 39.6 kg/100 m for a similar steel-reinforced cable. The reduction in weight is possible because Kevlar fibers are ten times as strong as steel wires when compared on a weight basis. The relatively low shear strength of the Kevlar fibers suggests caution in their use.

In addition, this cable has a bending diameter of 30x the cable diameter (1 cm) which reduces component size requirements by a factor of nearly two. Termination problems with this type of cable have been eliminated in recent years and have resulted in a termination strength of 100 percent of cable strength.

The use of composite inner and outer barrels, similar to the barrel used on the PICO lightweight hand auger, diminishes drill weight without sacrificing performance in ice

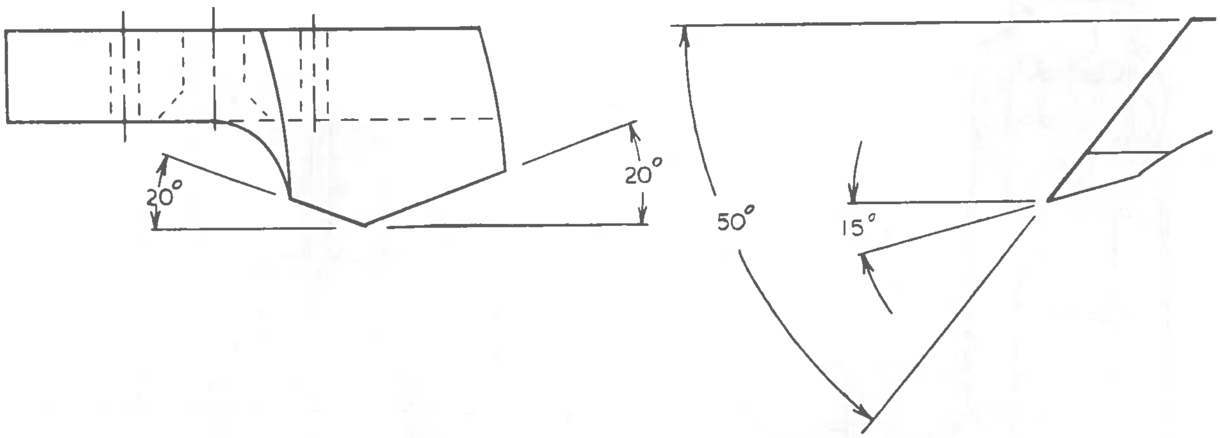

Figure 2. Self-centering bit

above -25°C. The inner barrel is constructed exactly as the hand auger barrel is, while the outer barrel has ribs on the inside formed as an integral part of the tube.

Since this drill has been designed as a system, we are adding the capability of electrothermal coring. Hermetically-sealed heaters of less than 1.5 mm diameter and watt densities as high as $100 W/cm^2$ are brazed to a stainless steel ring, and provide a penetration rate greater than 4 m/hour with approximately 1200-watt power input. The core diameter in this case is 8.5 cm while the melted hole is approximately 10 cm.

By reducing the drill weight and core break requirements which we demonstrated at South Pole Station during 1981-82, power and torque requirements are kept small. This allows the use of small gear reducers and standard motors, or a pair of 135 N-m torquing motors that weigh about 10 kg apiece. Thus, all components of the winch package weigh less than 20 kg, and will each fit into a backpack. Drawings of the winch and tower are given as Figures 3, 4, and 5. A tensile structure is used as a shelter since the weight is less than 20 kg while providing adequate wind resistance.

Since the power requirements are on the order of 1000 watts, the possibility of using solar power becomes realistic. Twenty-five 37-watt panels will provide the required power since each produces about 45-watts because of the ultraviolet light reflected from the snow surface. These Solarex panels are .7 m square and weigh approximately 5 kg each.

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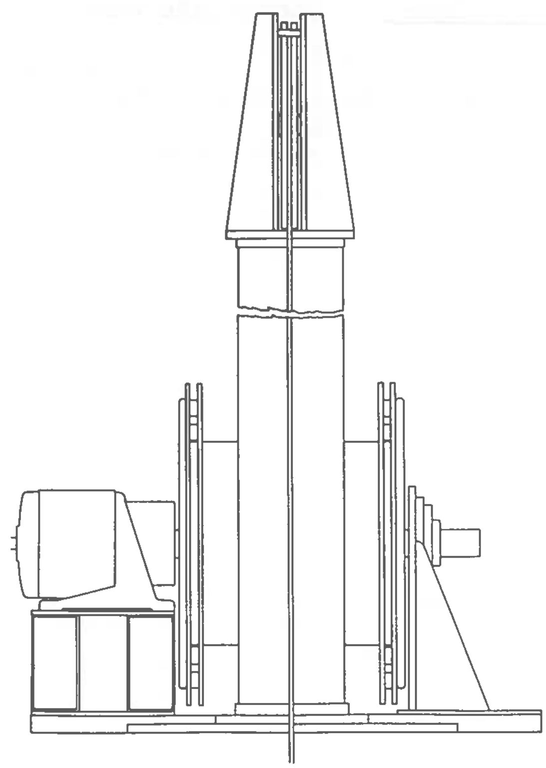

Figure 3. Winch: Front View

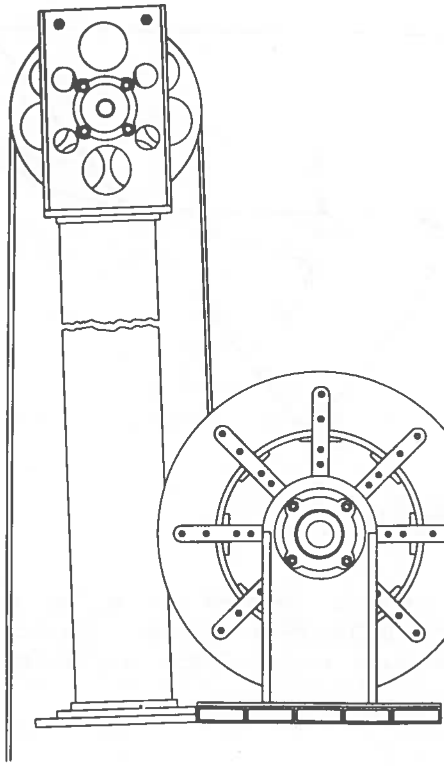

Figure 4. Winch: Side View

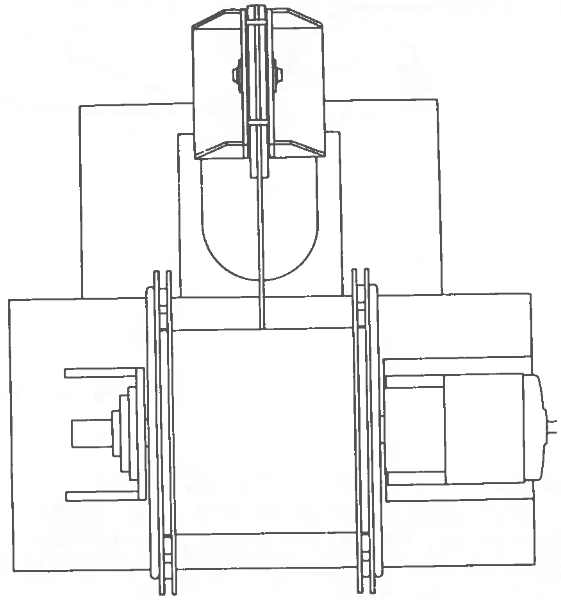

Figure 5. Winch: Top View