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Design and development of Multi Parameter Probe (MPP) to measure temperature and hardness inside snow microstructure

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CSIO Chandigarh has developed a portable Multi Parameter Probe (MPP) to measure temperature and hardness in snow pack. MPP has been tested in snow bound areas in and around Manali in association with SASE (DRDO). In this paper, designing of MPP and field test performance results provide valuable assistance in the study of snow and avalanche pattern over a period of time, thus improving research accuracy and validating research findings.

Keywords: Hardness, Multi Parameter Probe (MPP), Snow pack, Temperature

Introduction

A typical seasonal snow cover is composed of several layers arranged more or less parallel to the soil. Individual snow layers result from various precipitation and snowdrift events. Seasonal snow directly affects life of residents by the danger of avalanches and spring floods in villages living on winter tourism. Reliable avalanche forecast and prevention requires detailed knowledge on properties and composition of snow cover. Several methods[1-3] exist to measure quantitative snow properties in steep slopes, which are only accessible by skis, snowshoes, or helicopter. Snow Micro Pen (SMP)[1,2], developed by Swiss Federal Institute for Snow and Avalanche Research, measures force-resistance, which derives hardness. SABRE Penetrometer[3] also measures force resistance in snow cover. None of these instruments measures temperature of snow layer along with vertical force resistance/hardness.

In India, CSIO has developed successfully a snow penetrometer, named Multi Parameter Probe (MPP). The aim of research work is to design an instrument to measure temperature and hardness profile simultaneously with respect to depth of snowpack.

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Multi Parameter Probe (MPP) Design

Designing and components for MPP have been chosen in such a way, that it can operate in extremely harsh environmental conditions of glaciers. User-friendly operation, lightweight, ultra low power consumption and ruggedness are the main features of MPP[4]. Complete system has following three units (Fig.1):i) Micro-controller based main unit; ii) Motor drive & transducer assembly unit; and iii) Power supply unit. A fast response temperature transducer and quartz force sensor are used at the conical tip of steel rod, which is fitted with motorized drive mechanism. During operation, motor mechanism drives conical tip into snow pack, which senses temperature and force-resistance variations of snow pack.

Technical specifications of MPP are as follows: i) It can test new snow (50 kgm^3) to very dense snow occurring on ski race track (500 kgm^3); ii) It measures force (0-500 N) at every 0.1 mm; iii) It measures temperature at every 1 mm (–50°C to +50°C); iv) It has user selectable penetration speed (range 1-20 mm/s); and v) It can store 4 MB data [minimum 111 full length (1700 mm) measurement data]. Maximum force measurement for different type of snow is as follows: hard snow with ice crusts, 43; very hard snow without ice, 22; hard snow, 9; soft snow, 4; ski race tracks, 435; thick ice crusts, 217; and ice crusts, 87 N.

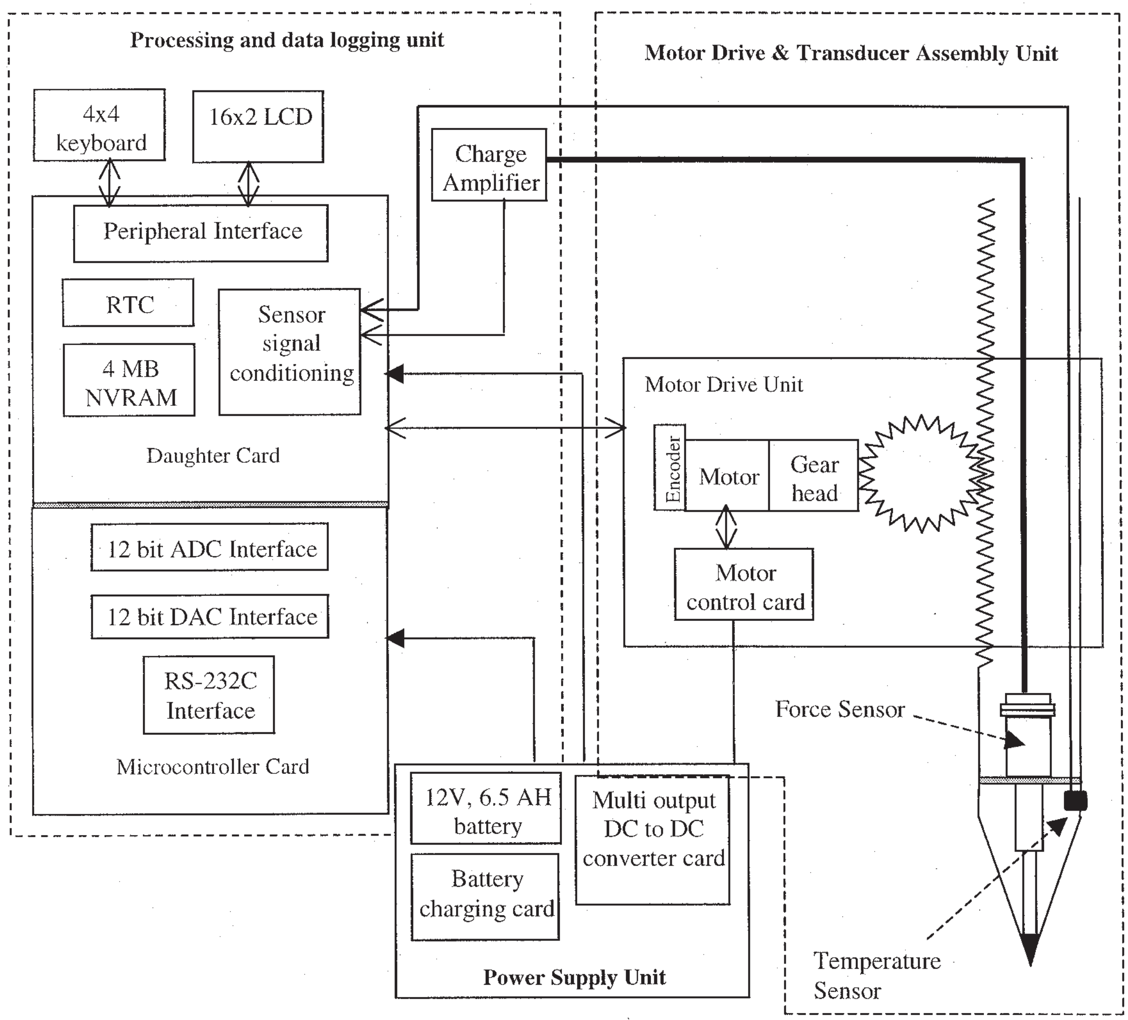

Fig. 1—Block diagram of Multi Parameter Probe (MPP)

Microcontroller based Main Unit

It houses a C8051F120 microcontroller[5] based main processor card, a daughter card and charge amplifier card. Processor card controls overall working of the instrument. Processor card and daughter card are interconnected through 96-pin euro connector. Daughter card is designed with SM Bus protocol based Real Time Clock, 4 MB NVRAM (2 ×2 MB) with build in battery backup, 16 x 2 characters alphanumeric LCD interface, 4 x 4 matrix keyboard interface, signal conditioning circuitry for temperature sensor (K-type thermocouple) and general purpose I/O lines.

Miniature charge amplifier converts electrical charge signals yielded by piezoelectric sensor into proportional voltage signal. This force signal and output of temperature sensor after signal conditioning are fed to 12-bit ADC on processor card, which stores measured force and temperature values in NVRAM along with measured depth information. Complete system is totally interactive and operated through direct instructions using its driver software program loaded into flash memory. Stored data can be transferred to PC/laptop through RS232C interface at 115.2 kbps.

Motor Drive and Transducer Assembly Unit

Highly sensitive quartz force sensor[6] and K-type thermocouple are fabricated at conical tip of steel rod. Force to be measured is introduced into quartz element fitted in transducer via cylindrical force introduction part. The element is preloaded to enable both tensile and

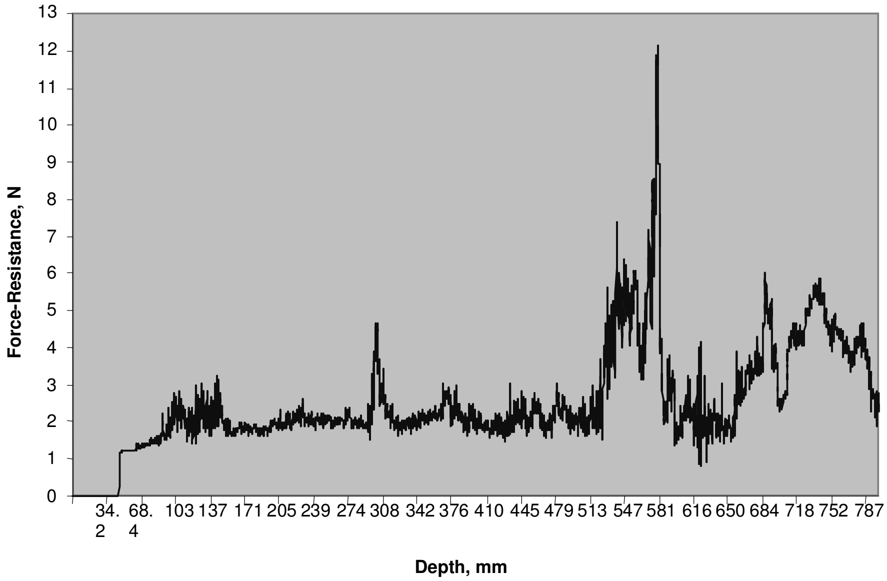

Fig. 2—Force-resistance plot of natural snowpack measured by CSIO developed MPP

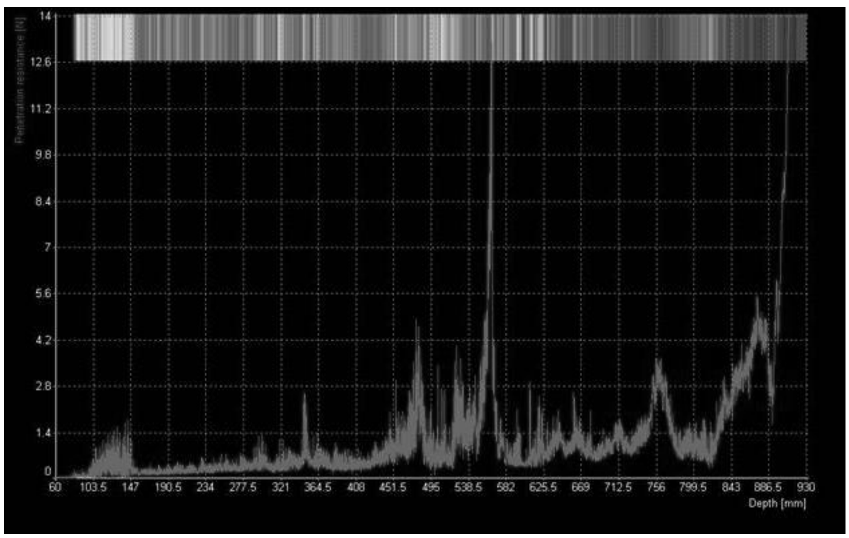

Fig. 3—Force-resistance plot of natural snowpack measured by SMP

compressive forces to be measured. Quartz measuring element generates an electrical charge proportional to force, which is converted into voltage by charge amplifier.

Quartz sensor has remarkable properties as: i) High material stress limit, approx. 20,000 psi; ii) Temperature resistance up to 500°C; iii) Very high rigidity, high linearity and negligible hysteresis; iv) Almost constant sensitivity over a wide temperature range; and v) Ultra high insulation resistance allowing low frequency measurements (<1 Hz).

A DC motor (120 watt) drives conical tip of probe into snow pack through rack pinion arrangement. Gear head is attached with motor shaft to increase torque so that probe does not skid over pinion. An encoder is attached to the motor opposite to gear head[7]. It gives pulses, which are used to measure the distance traveled by conical tip in snowpack. Conical tip can go maximum 1700 mm deep in snowpack.

Power Supply Unit

It provides necessary voltage and current requirement of complete system. In power supply unit, a battery (12

V, 6.5 Ah) and SMPS is used. SMPS gives different voltage levels (+24 V, ±12 V & ±5 V), required to operate this unit.

Results

Force sensor was calibrated in laboratory conditions by giving known force resistance in simulated conditions. MPP prototype was tested in field in and around Manali, Himachal Pradesh, in association with SASE. Performance of MPP was compared with field proven SMP already being used by SASE. Both instruments were simultaneously operated in similar conditions. Temperature measurement accuracy was tested in laboratory and field conditions using precision thermometers. Force-resistance profile plot of natural field snow measured with CSIO developed MPP (Fig. 2) and that by SMP already being used by SASE (Fig. 3) were taken 15 cm apart from each other. Both plots show melt-freeze crust at same depth. These plots also show that snow above melt-freeze crust is weaker than the snow below it. Results from MPP were encouraging and found comparable with SMP.

Conclusions

MPP system has been designed and developed successfully at CSIO Chandigarh in association with SASE. It has a novelty over other instruments already in international market that it can measure both force-resistance and temperature of various layers in snowpack. MPP provides a technique to quickly measure snow penetration resistance and temperature without opening a snow pit. The results obtained by MPP were found comparable with imported units already available with SASE. In this design, force measurement is taken at every 0.1 mm interval and temperature at 1 mm interval. More research can be carried out to reduce further this interval and a graphical LCD display can be implemented for *in situ* visualization of force- resistance and temperatures profile of the snow microstructure.

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