A MECHANICAL DEVICE DETERMINING THE VOLUMETRIC LIQUID WATER CONTENT OF SNOW - SNOWPRESS

Reinhard Fromm[1]*, Adriano Riml[2], Arno Penz[2] and Roland Peinelt[2]

[1] *Department of Natural Hazards, Austrian Research Centre for Forests, Austria*
[2] *Höhere Technische Bundeslehranstalt, Fulpmes, Austria*

ABSTRACT: The measurement of the liquid water content of snow is not an easy task. Existing methods are based on different physical processes. The proposed method uses the mass difference which is caused by a mechanical press on a snow probe.
The construction of the equipment is demonstrated and first measurements are compared with data gained from Denoth's capacity snow moisture device. At this stage of development, the quality of the data is insufficient for further application. However, advantages and disadvantages are discussed and possible improvements suggested.

KEYWORDS: mechanical press, perforated cylinder, spindle drive.

1. INTRODUCTION

A melting snowpack consists of ice, air and liquid water. The liquid water content is defined by the *International Classification of Seasonal Snow on the Ground* (Fierz et al., 2009). It is relevant for investigations concerning the mechanical stability of wet snow (Mitterer et al., 2011) or for hydrological issues (Hardy et al., 1998).

The amount of liquid water can directly be determined with centrifugal equipments which are hand operated (LaChapelle, 1955) or electrically powered (Yosida, 1967). Indirect methods can be classified into 3 groups: calorimetric methods (Boyne and Fisk, 1990), capacitively methods (Ambach and Denoth, 1974; Denoth, 1994; Tiuri and Sihvoly, 1986; Stähli et al., 2004; Mittal et al., 2009) and radar measurements (Gubler and Hiller, 1984; Boyne and George, 1987; Okorn et al., 2014).

A simple method for estimating the liquid water content in the field is the hand test (Fierz et al., 2009). However, it depends on human factors which makes it prone to errors.

The objective of this study is to develop a new device which operates purely mechanical. Field data are compared with acquisitions from Denoth's device (Denoth, 1994). The pros and cons are discussed.

* *Corresponding author address:*
Reinhard Fromm, Institute of Natural Hazards, Austrian Research Centre for Forests, Austria, Rennweg 1, 6020 Innsbruck, Austria;
tel: +43 512 573933-5104; fax: +43 512 573933 -5250
email: reinhard.fromm@bfw.gv.at

2. METHODS

The basic idea is to reconstruct the hand test with a mechanical equipment. The human grip force is estimated from the study of Massy-Westropp et al. (2011).

The construction is a mechanical press of a cylindrical snow probe. Hence, it is called SNOWPRESS. Figure 1 shows the primary elements of the device. A comprehensive description concerning the development of the SNOWPRESS is given by Penz and Riml (2018).

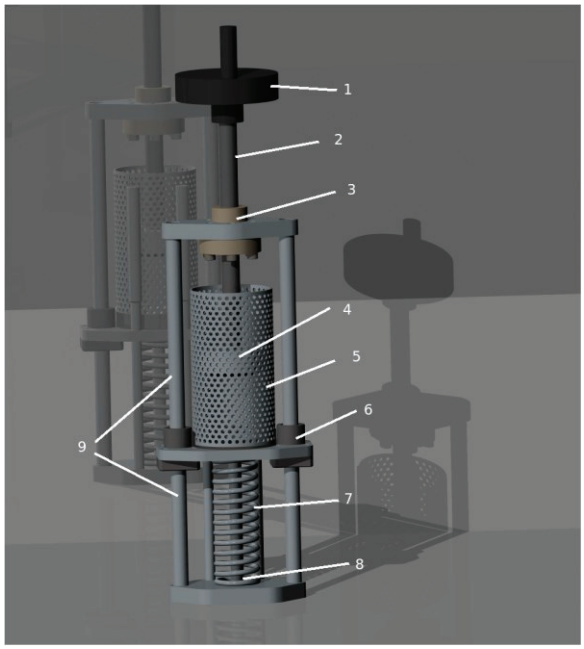

Figure 1: Conceptual design of the SNOWPRESS: 1 = crank lever, 2 = spindle, 3 = spindle drive with shaft joint, 4 = (inside) ram cylinder, 5 = perforated cylinder which contains the snow probe, 6 = slider, 7 = spring, 8 = bolt, 9 = slide.

The workflow for a measurement is simple and can be divided into 4 steps:

1. Extract a snow probe with the perforated cylinder (diameter: 6 cm; length: 12 cm; holes: 3 mm) from the snowpack and weigh it.

2. Immediately insert the cylinder filled with snow into the mechanism. Turn the crank and observe the rising force of the spring tension. Markers on the bolt (8, Fig. 1) indicate the force acting on the probe. Water may be extruded from the snow probe. Stop when the threshold force (500 N) is reached and wait. Turn the crank to ensure a constant force during the measurement.

3. After 10 minutes remove the cylinder and weigh the probe again.

4. Calculate the volumetric liquid water content of the snow probe with the mass difference before and after the procedure. One gram (= 0.001 kg) mass difference corresponds to 0.29 vol% liquid water content.

3. RESULTS

In order to gain experience with the SNOWPRESS field measurements were carried out. Figure 2 shows the device on a blanket . The cylinder is filled with snow. A force is applied by the spindle. The spring is compressed and the bolt (8, Fig. 1) overhang from the device which makes the markers visible. Snow is extruded through the perforation.

The comparison with acquisitions from the Denoth meter requires additional equipments (Fig. 3).

Figure 4 shows the comparison of data sets which were collected during 5 field campagnes. The acquisitions 2018-03-27 and 2018-05-11 indicate that the SNOWPRESS starts at certain thresholds of liquid water content (determined by Denoth meter). However, the other data sets have large variations without any trend.

Figure 2: SNOWPRESS in the field (photo by R. Fromm, 18 April 2018).

Figure 3: Foto of equipment in the field: electronic scale, aluminium quader for measuring snow density, Denoth meter, brush, SNOWPRESS (photo by R. Fromm, 18 April 2018).

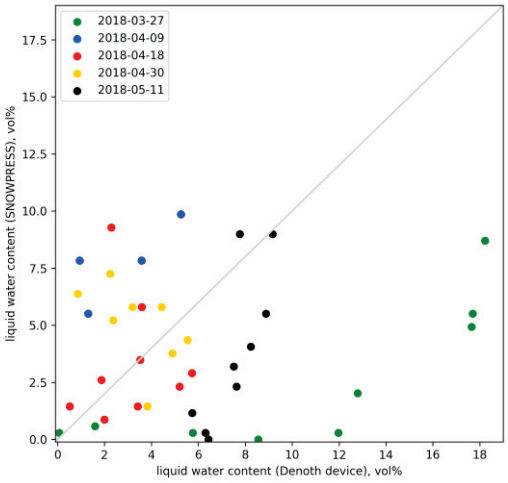

Figure 4: Scatter plot of liquid water content acquired by different methods.

4. DISCUSSION AND CONCLUSIONS

The SNOWPRESS is a preliminary mechanical device for quantifying the liquid water content of snow. At this stage of development it is not an adequate alternative to Denoth's capacity snow moisture device.

Pros:

- It is a direct measurement of the liquid water content of snow.
- The device is mobile, it can be used in the field and it does not need any power which makes field work easier (in contrary to electric centrifuges).

Cons:

- The data quality is insufficient.
- Depending on the snow conditions snow can be squeezed through the holes in the cylinder.

Future & Improvements:

- The size of the cylinder could be reduced. The diameter of the holes of the perforated cylinder should be larger which would stimulate the run-off. However, more snow would be extruded. Maybe, it could help to modify the shape of the ram cylinder (4, Fig. 1; e.g. cone-shaped).
- The spring could be changed to apply a higher force on the snow probe. However, this requires smaller holes in the cylinder.

ACKNOWLEDGEMENT

The development of the SNOWPRESS was predominantly carried out as part of a diploma thesis at the HTL-Fulpmes by Adriano Riml and Arno Penz (Penz and Riml, 2018). They were supervised by Roland Peinelt.

The authors thank the management of the school and the subject teachers for their support.

REFERENCES

Ambach, W. und Denoth, A., 1974. On the dielectric constant of wet snow. IAHS-Publ. 114: 136-142.

Boyne, H.S. and George, D., 1987. Microwave determination of liquid water content in snow cover. Avalanche Formation, Movement and Effects (Proceedings of the Davos Symposium, September 1986). IAHS Publ. no. 162, 1987.

Boyne, H.S. and Fisk, D.F., 1990. A Laboratory Comparison of Field Techniques for Measurement of the Liquid Water Fraction of Snow. U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory, Special Report 90-3, 8 pages.

Denoth, A., 1994. An electronic device for long-term snow wetness recording. Annals of Glaciology, 19: 104-106.

Fierz, C., Armstrong, R.L., Durand, Y., Etchevers, P., Greene, E., McClung, D.M., Nishimura, K., Satyawali, P.K. and Sokratov, S.A., 2009. The International Classification for Seasonal Snow on the Ground. IHP-VII Technical Documents in Hydrology N°83, IACS Contribution N°1, UNESCO-IHP, Paris.

Gubler, H. and Hiller, M., 1984. The use of microwave FMCW radar in snow and avalanche research. Cold Regions Science and Technology, 9: 109-119.

Hardy, J., Albert, M. and Marsh, P., 1998. The Integration of Physical, Chemical, and Biological Systems. Abstracts from the International Conference on Snow Hydrology, 6–9 October 1998, Brownsville, Vermont, USA, Special Report 98-10, 112 pages.

LaChapelle, E.R., 1955. Centrifugal separation of free water from snow. Journal of Glaciology, 2(20), Seite: 769-771.

Mittal, S.K., Singh, M. and Garg, M.K., 2009. Development of an instrument to measure density and moisture content of snow. Journal of Scientific and Industrial Research, 68: 188-191.

Massy-Westropp, N.M., Gill, T.K., Taylor, A.W., Bohannon, R.W. and Hill, C.L., 2011. Hand Grip Strength: age and gender stratified normative data in a population-based study. BMC Research Notes 2011, 4:127, 5 pages.

Mitterer C., Hirashima, H. and Schweizer J., 2011. Wet-snow instabilities: comparison of measured and modelled liquid water content and snow stratigraphy. Annals of Glaciology, 52(58): 201-208.

Okorn, R., Brunnhofer, G., Platzer, T., Heilig, A., Schmid, L., Mitterer, C., Schweizer, J. and Eisen, O., 2014. Upward-looking L-band FMCW radar for snow cover monitoring. Cold Regions Science and Technology, 103: 31-40.

Penz, A. and Riml, A., 2018. SNOWPRESS - Entwicklung eines Messinstruments zur Bestimmung des Flüssigwasseranteils von Schnee. Diplomarbeit im Rahmen der Reife- und Diplomprüfung, HTL Fulpmes, Tyrol, Austria, 105 pages.

Stähli, M., Stacheder, M., Gustafsson, D., Schlaeger, S., Schneebeli, M. and Brandelik, A., 2004. A new in situ sensor for large-scale snowcover monitoring. Annals of Glaciology, 38: 273-279.

Tiuri, M. and Sihvoly, A., 1986. Snow fork for field determination of the density and wetness profiles of a snow pack. Hydrologie Applications of Space Technology (Proceedings of the Cocoa Beach. Workshop, Florida, August 1985, IAHS Publ. no. 160, 1986: 225-230.

Yosida, Z., 1967. Free Water Content of Wet Snow. Physics of Snow and Ice: proceedings on low temperature science, 1(2), Seite: 773-84.