A PAINT SCRAPER HARDNESS BLADE

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ABSTRACT: We present a new hand-held hardness gauge that measures penetration resistance over a length scale of about 100 grains. The apparatus consists of a 10 cm wide, 0.5 mm thick stainless steel blade with a sharpened leading edge attached to a digital push-pull gauge. The maximum force of penetration was recorded as the blade penetration index ("B"). The blade itself was adapted from an off-the-shelf paint scraper, so the only significant cost is in the choice of the push-pull gauge. The narrow profile of the blade minimizes the compression and densification of snow that is common to nearly all other hardness measures. Blade penetration measurements are easy to conduct, require no post-processing or subjective judgements to interpret, and are highly repeatable compared to the hand hardness test. The gauge is useful for tracking the transition from storm snow (or otherwise cohesionless snow) to slab snow with increasing penetration resistance. The shape of the blade allows the relative hardness of slab and weak layers to be tracked. We present here details on the design and use of the blade hardness gauge and some general results.

1. INTRODUCTION

The resisting force in most measures of snow hardness come from a combination of bond or grain ruptures, frictional rearrangement and compaction of loose grains around the penetrating object and friction between the snow and the penetrating object. The relative contribution of each of the components of penetration resistance is unknown. However, Floyer and Jamieson (2006) demonstrated that rounded and conical-tipped probe penetrometers create much larger zones of compaction compared to a blade tip.

From the perspective of the fracture mechanics of slab avalanches, the rupturing of bonds and grains is the most important component of a hardness measure. Moreover, the scale of interest for avalanche fractures is greater than the individual grain size. Shear and tensile fractures do not become critical until they achieve a size of roughly 10-100 times the grain size or more (Bažant et al. 2003, Borstad and McClung 2009).

Based on these findings, we developed a hand-held blade hardness gauge that minimizes the effects of compaction relative to other common hardness measurements. The width of the blade was chosen in order to measure the penetration resistance of around 100 grains simultaneously in contact with the blade. The measurement is easy to carry out and the results are consistent across observers. The blade gauge distinguishes between loose and cohesive snow and can be used to track the relative hardness of slab-weak layer combinations.

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2. BLADE GAUGE DESIGN

The blade hardness gauge consists of an adapted paint scraper blade attached to a digital push-pull gauge. Figure 1 shows the blade, which has a width of 10 cm, a thickness of 0.5 mm and a sharpened leading edge.

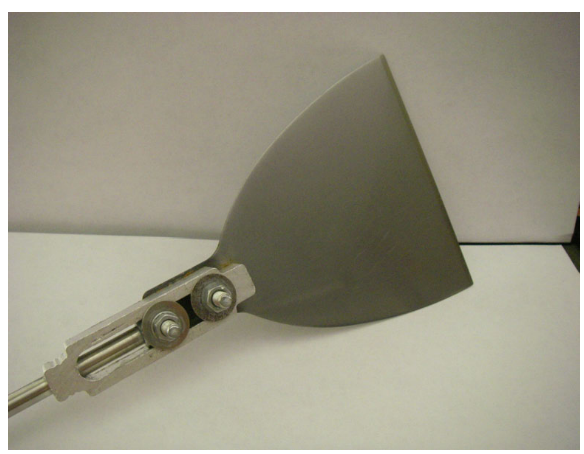

Figure 1. Paint scraper blade, showing attachment to threaded rod using an aluminum turnbuckle and two bolts.

The force gauge had a capacity of 250 N (approximately 25 kgf or 50 lbf) and a resolution of 0.1 N. However, the maximum force of penetration rarely exceeded 25 N and the gauge had accuracy problems at the low end of the scale (below 2 N). Therefore a 50 N capacity force gauge with at least 0.1 N resolution would be more appropriate for resolving softer snow. An analog or digital force gauge could be used as long as the gauge has the capability to record or hold the peak force.

To attach the blade to the force gauge, the plastic handle of the paint scraper was first removed. An aluminum turnbuckle and two bolts were used to clamp the blade to a threaded rod that extends from the force gauge (Figure 2).

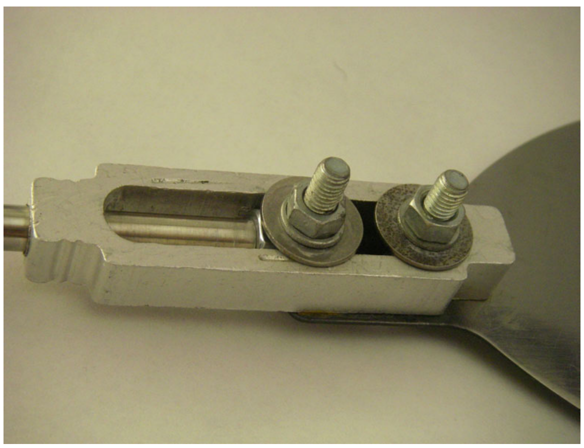

Figure 2. Close-up of turnbuckle attachment. The large washer on the left bolt clamps a nut (just visible) that the threaded rod screws into.

3. METHODS

Blade hardness measurements were carried out by pushing the blade 3-5 cm into an exposed pit wall at a penetration speed of around 10 cm/s (Figure 3). The blade was then withdrawn and the maximum force of penetration was read from the gauge. As a reference, the rate of penetration was faster than most people conduct hand hardness tests. The purpose of a fast rate of penetration was to minimize rate effects and maximize consistency across observers. Fukue (1977) showed that thin blade penetration resistance into snow was rate independent as long as the penetration speed was above about 1 mm/s.

The blade hardness index was defined as the maximum force of penetration. This was recorded using the notation 'B_{10}' with the 'B' distinguishing blade hardness from other hardness measures. The subscript '10' indicates that a 10 cm wide blade was used.

Figure 3. Demonstration of a blade hardness measurement. The standard orientation of the blade was parallel to the snow stratigraphy.

4. RESULTS AND DISCUSSION

The blade hardness results were hightly repeatable compared to the hand hardness test. Within the typical scatter of results, no statistically significant difference between results obtained by different operators, for the same snow layer, could be detected.

The digital force gauge had sensitivity problems below 2 N, but a threshold penetration force distinguishing loose from cohesive snow was identified between 0 and 2 N. A new force gauge with more sensitivity at the low end of the scale will be used to determine with more accuracy the value of penetration resistance that distinguishes loose snow from slab snow.

An advantage of the thin profile of the blade hardness gauge was the ability to measure thin layers. The gauge can be used to track the relative hardness, and therefore strength, of slab-weak layer combinations.

Though density is the most commonly used index variable for other mechanical properties of snow, the blade hardness index proved better in hundreds of laboratory fracture experiments for predicting the tensile strength and elastic modulus of the samples.

5. REFERENCES

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