A MEASURING INSTRUMENT FOR THE HARDNESS AND THE ROUGHNESS OF THE SKI SLOPE – CORRELATION TO THE GLIDING PROPERTIES OF SKIS

PENETROMETER AND PROFILOMETER

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ABSTRACT: The analysis of the ski slope is crucial for understanding the gliding of skis. Especially in ski racing a detailed knowledge of the parameters of the snow influencing the gliding properties helps to optimize the skis. Unfortunately, the analysis of the slope surface is limited to only a few parameters like snow temperature, air humidity and air temperature, so far. We proved that there is a large number of parameters concerning directly the snow surface like snow humidity, hardness, roughness, grain size, thermal conductivity and more that are strongly influencing the gliding properties. This paper presents a tool developed at the Swiss Federal Institute for Snow and Avalanche Research for measuring the hardness and the roughness of ski slopes. Results of gliding tests prove the correlation of these two parameters to better gliding.

KEYWORDS: ski slope, hardness, roughness, gliding, skiing.

1. INTRODUCTION

The gliding properties of polyethylen on snow depend on a large number of parameters of the weather conditions and the snow conditions besides the characteristics of the ski itself [Buhl, Colbeck]. Especially the characterization of the snow surface is crucial for the understanding of the tribological effects describing the friction between ski and snow.

Unfortunately, this analysation has been restricted to only a few parameters like density, temperature and grain size, so far. Others like thermal conductivity or wetness are hardly known and difficult to measure. From the tribological point of view the knowledge of the hardness and the roughness of the snow surface is important in order to estimate the friction between ski and snow.

The purpose of the present work was the development of a tool measuring both, the hardness and the roughness of the snow surface [Schneebeli]. Therefore, the snow profile of the slope has to be measured with a high resolution especially for the first millimetres and the profile of the surface has to be recorded. It turned out that the combination of these two features enables to estimate the contact area between ski and snow, as well.

During gliding tests of skis on snow the hardness and the roughness of the slope were constantly measured. It is shown that there exists a strong correlation between both parameters and the gliding properties. The numerical quantity of the parameters is compared with the coefficient of friction. In addition, an estimation of the contact area shows its influence on the gliding properties, as well.

2. EXPERIMENTAL

A penetrometer was fixed on a sledge in order to be able to perform field measurements with this mobile measuring instrument. The main parts of the penetrometer are the engine unit as a prime mover, the sensor measuring the resistance and the electronic unit recording the signals of the sensor and transforming them into practicable values. The hardness value indicates the resistance offered by the snow surface and the layers beneath to the vertical penetration of a metal cone of given dimensions. The cone is connected to the sensor and driven into the ground by the engine unit. Different shapes of the metal were used for investigations of the surface (stamp) and the depth profile (standard 30° cone).

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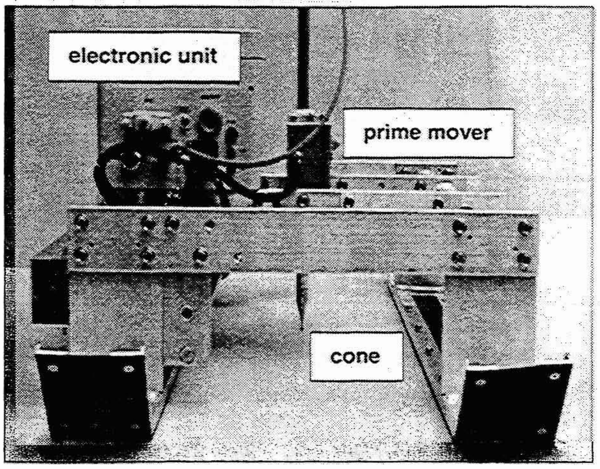

Figure 1: Penetrometer for measuring the hardness of the ski slope.

On the same sledge, there was mounted a profilometer for measuring the profile of the snow surface. The main parts of the profilometer are the engine unit as a prime mover, a laser measuring the distance to the snow surface and the electronic unit recording the signals of the sensor and transforming them into distance values. The laser is moved at a constant rate horizontally above the snow surface. The snow surface is dusted with black powder in order to enable maximum reflection of the laser beam. Thus, the distance between the laser and the snow surface is recorded as a function of the position of the laser and the data enables to draw the profile of the surface. The profile is further analysed by standard methods and a large number of roughness values are determined.

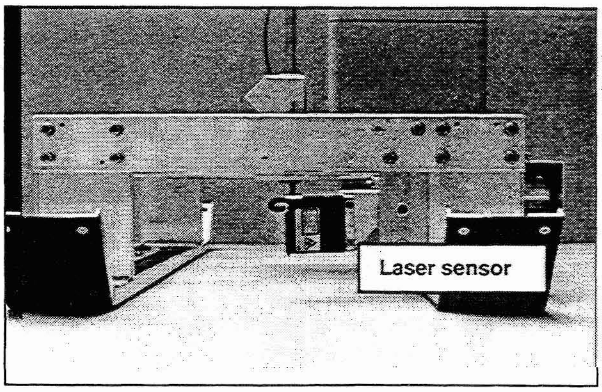

Figure 2: Profilometer for measuring the roughness of the ski slope.

3. RESULTS

In figure 3 the snow profile of a racing slope is shown, measured on the same spot at two different times. Two hard layers are visible at the first measurement. One is on the surface, the other one is at 15 cm depth. It is suggested, that this second layer once was the surface of the slope before it was covered by fresh snow. Two hours later this second layer remains unchanged, whereas the surface has significantly weakened by about 50%. The surface has split into three different layers which is a result of the repeated passing of skis.

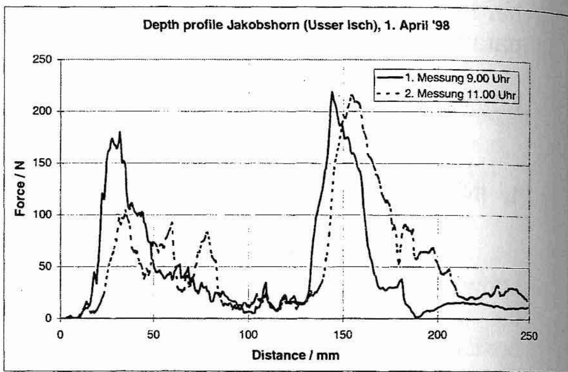

Figure 3: Penetration of a ski slope, penetration force as a function of depth at two different times

Figure 4 shows the Abbott curve of the snow surface. From the profile, the amount of snow as a function of the depth is determined (on top of the surface, the amount is 0%, in a depth of 2.2 mm the amount is 100%). Measuring the penetration depth for a load of 2.5 MPa (performed by a stamp, corresponding to the average pressure distribution of a skier) gives 0.28 mm (x_1) and thus a contact area of 8% (M_1). The penetration depth two hours later has increased to 0.56 mm (x_2) which results in a contact area of 37% (M_2).

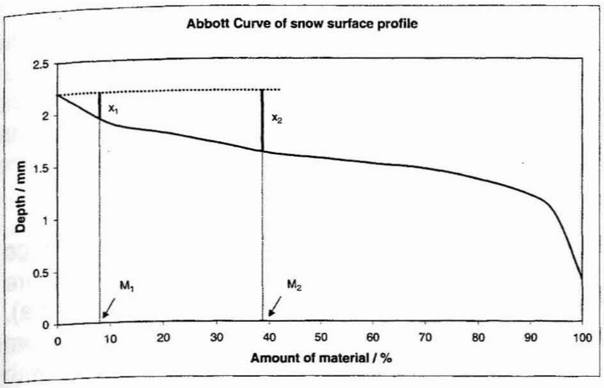

Figure 4: Abbott curve of the snow surface giving the amount of snow at a defined depth.

4. DISCUSSION AND CONCLUSIONS

The influence of the hardness and the roughness on the gliding properties are investigated. Therefore, the force for the penetration into a depth of 5 mm from the snow surface was measured and the roughness extracted from the profile of the snow surface during several days while gliding tests where performed on the slope. Figure 3 shows that the gliding performance of the skis strongly decreases with decreasing hardness of the slope.

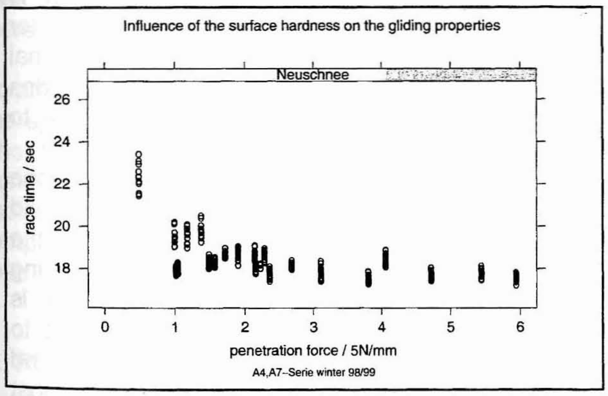

Figure 5: Gliding time versus surface hardness. The skis are faster with increasing hardness up to about 2.5 N/mm.

Figure 6 shows that the gliding performance of the skis is increased with increasing roughness of the snow surface.

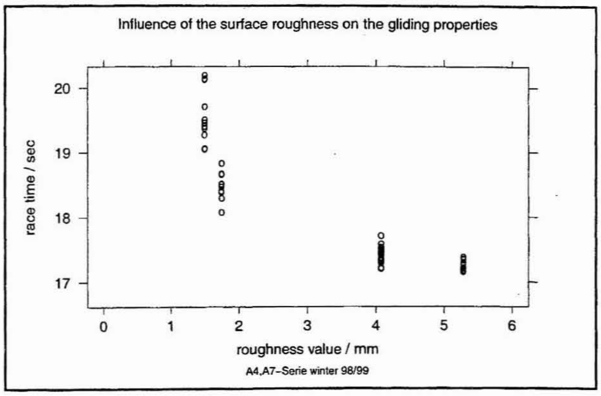

Figure 6: Gliding time versus surface roughness. The skis are faster with increasing roughness.

5. ACKNOWLEDGEMENTS

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