High-Speed Video Recording in Snow Chute Experiments

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Abstract

New technologies like high-speed video recording give new insights into the flowing behavior of snow. At the SLF snow chute at Weissfluhjoch Davos a setup was developed, which allowed us to record high-speed movies of the ground near shear layer of the chute flows with a frame rate of 1000 frames per second. Frictional and collisional processes can be observed in high slow motion in the videos obtained. Downstream velocity profiles were generated by a pattern matching algorithm and compared to velocity profiles obtained from optical sensors mounted next to the high-speed camera. The comparison shows good agreement for most experiments. The temporal and spatial resolution is much higher for the high-speed video data. Because the optical velocity sensors only measure velocities in downstream direction they overestimate the velocities when flow-normal velocity components exist as well. All measured velocity profiles show very high shear rates near the ground. The height of the this highly sheared zone depends on snow properties. Above this highly sheared zone the shear rates decrease significantly tending to zero for certain snow types.

Key words: avalanche dynamics, high-speed video recording, snow rheology, chute experiments, pattern matching algorithm

1. Introduction

Snow chute experiments are an important tool to study the flowing behaviour of snow under controlled conditions. The WSL Institute for Snow and Avalanche Research (SLF) operates a 30 m long and 2.5 m wide chute at Weissfluhjoch near Davos, Switzerland (Fig.1). It has been renovated and equipped with a great variety of sensors in the beginning of this decade (Tiefenbacher and Kern, 2004). Slip velocities as well as internal velocities could be measured by cross-correlating reflectivity signals of optical sensors (Kern et al., 2004). By mounting arrays of optical sensors on a half wedge in the centre of the snow chute Kern et al. were able to measure internal velocity profiles of the avalanches. They identified a highly sheared layer in the avalanche core next to the ground. Platzer et al. measured basal shear and normal forces of the chute flows by means of force plates (Platzer et al., 2007; Jaedicke et al.,

Figure 1: SLF snow chute

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Figure 2: (a) Half wedge installed on the SLF snow chute equipped with: high-speed camera with strobes, array of optical sensors (b) typical image recorded by the camera: ground on the left top on the right

2007). They concluded that the basal friction could be satisfactory modelled with a coulomb friction model, where the coulomb friction parameter depends on snow properties. However considering the conducted experiments they could not exclude a velocity dependence of the basal friction. In order to better understand the physical processes that take place in the ground near highly sheared layer a high-speed camera was installed which is able to record movies of the flow at frame rate of 1000 frames per second.

2. Experimental Setup

The chute consists of a 20 m long storage and acceleration section, a 4 m long measurement section and a 6 m long run-out. Experiments are performed by releasing up to 15 m^3 of snow from the storage part by opening a shutter door. The inclination of the uppermost section of the chute is $45°$, of the measurement section $40°$ and in the run-out zone only $8°$. Flow velocities are in the range of 6 to 10 m/s and flow heights of some 10 cm can be generated, depending on the snow properties. The snow chute experimental site (Fig.1) is described in more detail in Tiefenbacher and Kern (2004). The high-speed camera was installed in the half wedge in the centre line of the chute, where we were able to record over a mirror the lower 4 to 10 cm of the chute flow. The location in the half wedge was chosen to reduce sidewall friction effects to a minimum and to be able to compare the obtained data with the already installed array of optical sensors. In order to guarantee a good illumination of the camera images at a frame rate of 1000 images per second two high-speed stroboscopes were needed.

In Fig. 2 the final setup of the high-speed camera and the optical sensor array is shown. A typical image as recorded by the camera is also shown in Fig. 2. Using a pattern matching algorithm described in Schaefer et al. (2009) two dimensional velocity fields with a very high spatial and temporal resolution can be obtained from the high-speed video images.

3. Results

For comparison with the data of the optical sensor array velocity profiles were generated from the two dimensional velocity fields by regarding only the downstream components of the velocities and by averaging over downstream velocities which correspond to the same flow depth. In Fig.3 velocity profiles from two experiments obtained from the array of optical sensors and the camera images are shown. The velocity values of the optical sensors are averaged over a time window where good correlation of the different reflectivity signals could be found and the errorbars correspond to the standard deviations of the velocity signals in this time window. A typical time window length was one second. The different profiles plotted for the high-speed cameras correspond to different times inside the time window. The temporal averaging to obtain these velocity correspond to a much shorter time window of about 0.05 seconds. For the experiments shown a good agreement between the camera data and the optical sensor data is guaranteed. It can be easily seen that the high-speed camera can resolve much more precisely the variation of the downstream velocities. From the variation of the velocity profiles in time it can be recognized that turbulent effects must

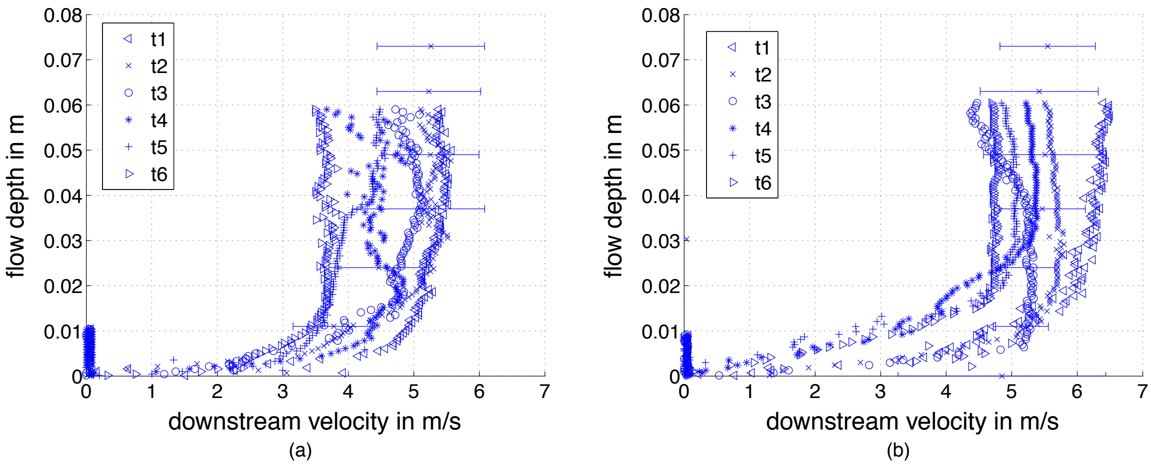

Figure 3: Comparison of velocity profiles obtained from the high-speed video recordings (symbols) and the optical sensors (bars): (a) avalanche with cold and relatively fresh snow; (b) avalanche at warmer ambient temperature and with transformed snow

exist in the ground near shear layer of the small chute avalanches.

4. Conclusions

A new setup has been presented that allows very detailed two dimensional velocity measurements in the shear layer of small scale avalanches released on the SLF snow chute. First analysis of downstream velocity profiles show good agreement with data from already installed optical velocity sensors. Signs of the turbulent structure of the flow in the shear layer could be identified. The great amount of new data obtained needs more study. In future work focus shall also be laid on the flow-normal components of the velocities.

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