On the hydrodynamic lubrication of skiing

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Snow and ice friction is a highly fascinating topic that affects our everyday life in wintertime. It is about maximising it under our shoes and bicycle tyres and it is about minimising it under our skis or sledges. Sports such as skiing, ice hockey, and curling are very popular and many of us struggle to optimise performance to make our sporting activities as enjoyable as possible.

The melt water theory by Bowden and Hughes 1939 is one important explanation to the low friction in skiing. The melt water theory suggests that a thin water film is formed due to the frictional heating and that the ski is separated from the snow by the thin film. Oksanen and Keinonen presented a theoretical model of the melting phenomena. They studied the heat balance of the ice-ski contact and were able to reach qualitatively correct friction values. They did not, however, take the fluid continuity into account, i.e., they did not show if the water film could be maintained during the time it takes for the ski to pass an ice asperity. This seems to be a major drawback of most modelling attempts of ski friction.

In this study we derive a continuity equation for skiing over a snow asperity, i.e. the Reynolds equation for skiing. The difference to normal hydrodynamic lubrication is the melting inside the contact. This implies that an additional term must be added to the continuity equation, the melt term.

Temperature is an important parameter since melting is involved. The friction will melt a thin boundary layer of water on top of the snow asperity. This water will be displaced from the contact by the ski motion and by the film pressure formed in the contact. The film thickness will thus be controlled by the rate of melting.

Here we assume that the ski surface is perfectly smooth, and the pressure is constant across the contact. We also assume that the snow grain has a spherical summit. By using realistic simplifications, it is possible to derive a semi-analytical expression for film thickness.

The outcome is a model which can be used to estimate water film thickness while taking the following parameters into account: snow temperature, grain size and hardness, and skiing speed. Comparison with experiments shows a reasonable agreement.

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