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NEW INSIGHTS IN THE PHYSICS OF ICE SKATING

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ABSTRACT

A liquid water layer is commonly believed to lubricate sliding friction on ice. Pressure melting, frictional heating and premelting have been proposed as mechanisms by which this lubricating water layer forms. Our recent experiments however provide an alternative explanation for the slipperiness of ice: weakly bonded surface water molecules diffuse over the ice surface in a rolling motion that facilitates the sliding [1].

The friction coefficient of steel-on-ice over a large temperature range reveal very high friction at low temperatures (−100 °C) and a steep decrease in the friction coefficient with increasing temperature. Only for a limited temperature range typical for ice skating, low friction is found. Remarkably, the strong decrease in the friction coefficient with increasing temperature exhibits Arrhenius behaviour with an activation energy of $E_a = 11.5\ kJ/mol$. Molecular dynamic simulations of the ice-air interface reveal a very similar activation energy for the mobility of surface molecules. The microscopic molecular mobility indicated that slippery ice arises from the high mobility of its surface molecules.

These sphere-on-ice model experiments did not probe the effect of slider geometry. Using spheres but also pieces of a real skate, we see that far from the melting point, similar frictional behaviour is observed for various slider geometries. However, close to the melting point we find that the plastic deformation of the ice depends on the geometry. We predict the ‘ploughing’ force based on the geometry of the slider and the independently measured hardness of the ice and find reasonable agreement with the friction measurements [2].

The slipperiness of ice then results from a layer of very mobile water molecules, combined with the fact that the ice remains very hard up to temperatures close to melting. This differentiates ice from other solids, and thus explains why skating is possible on ice, but not on other materials.

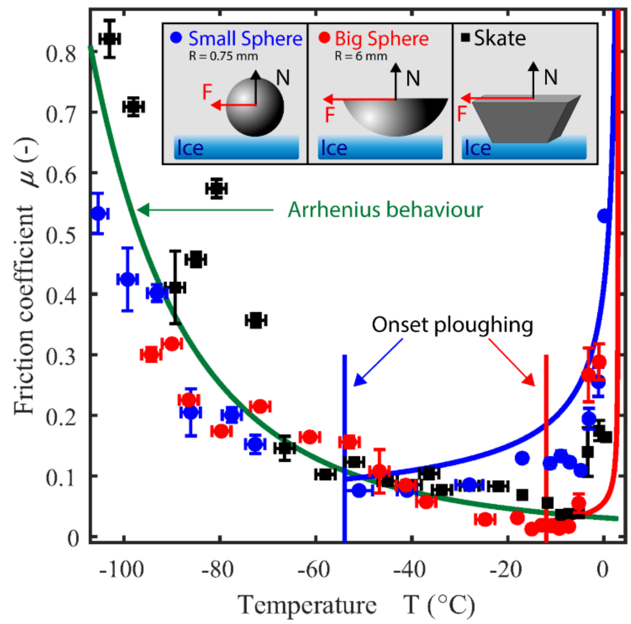

Fig.1 Friction coefficient as a function of temperature measured at a constant sliding speed (0.38 mm/s) for sliding a small sphere (blue, R = 0.75 mm), a big sphere (red, R = 6 mm) and a model skate (black) over ice. At low temperatures, the friction displays an Arrhenius temperature dependency which is independent on the geometry. Close to the melting point, plastic deformation occur which increases the friction; ploughing through ice can be modelled based on the temperature-dependent hardness of the ice and the geometry of the slider.

ACKNOWLEDGMENTS

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REFERENCES

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