Manufacture of well-described ice surfaces for ice/rubber friction tests

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Summary

Laboratory ice sheets has been grown and manufactured with controlled friction properties. Upper surface was treated by means of a modified planar tool and then by grinding methods in order to vary the topography. Friction between rubber and ice was measured from rotation tests with a circular contact area. At cold temperatures friction was relatively independent of ice treatment. At a temperature of -4°C and 2 bar contact pressure, friction was strongly dependent of the number of contact points to the rubber.

1. Introduction

Many tests have been done with the aim to measure the friction coefficient (μ) between rubber and ice without knowing much about the actual ice properties. Ice is a unique material in many ways. No other material shows such strength at the very melting point. Ice properties change rapidly with time which means that it is difficult to perform long test series. Properties of natural ice are different from one year to another due to the weather conditions during freezing. Therefore we decided to develop a simple method to grow sufficiently good ice for friction tests in the laboratory.

2. Preparation of ice surfaces

Columnar ice was grown in a water basin made of stainless steel with the dimensions 2x1x0.3m placed in a cold room. Ordinary tap water with a temperature of +18°C was pored into the basin and the water was cooled down to the freezing point. Shortly before freezing the water body was stirred to get close to +0°C. Initial ice formation was triggered by powdering the surface with sieved snow. Ice on a lake grows almost vertically but this is hard to simulate in a small basin. Along the poorly insulated sides of the basin the ice became disturbed and was not used in tests. Target ice thickness was 40mm which was thick enough to cut crack free samples with an electric circular saw. The air temperature was constant at -10°C after seeding and freezing took about 24 hrs. In figure 1 the crystal shape of the laboratory ice is shown.

Both the upper and lower ice surface was planned with a rotating knife. This procedure resulted in a wavelike surface with about 20 micron amplitude. Shaving off a thin layer also reduces foreign particles and the repeatability of friction tests was therefore assumed to be improved. A few different techniques to vary the topography from the standard planned were tried. Glossy ice was made by flooding with a thin water layer which was frozen at -10°C. Ice was also ground by hand with fine and coarse grinders. Another method was to blast snow with air pressure on the planned ice which produced a dull and frosty surface, see figure 2. Snow blasting seemed promising even for full scale treatment of large ice surfaces. Different from other methods it is capable to create a random roughness that can be varied by using different nozzles and air pressures.

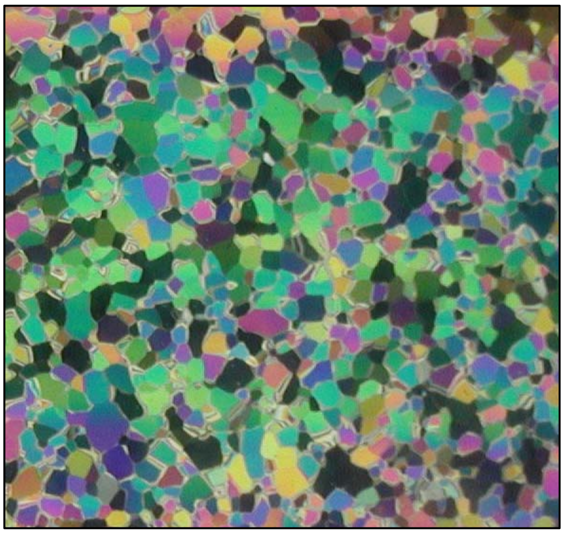

Fig. 1 Horizontal thin section of the ice showing the size distribution. The average crystal diameter was about 2 mm.

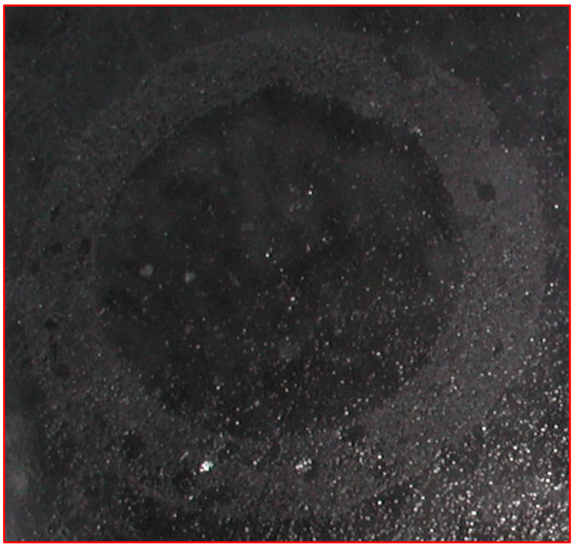

Fig. 2 Snow-blasted ice surface pictured after a friction test with a rubber ring.

3. Rubber/ice friction

One common method to measure the friction coefficient μ between two surfaces is to use an inclination table. If α is the angle when the object on the ice starts to move then $\mu = \tan \alpha$. We also tried to measure the angle when the object was moving with a constant velocity and named it the dynamic friction coefficient. When using an icehockey puck the static angle on the planned ice was 15-20 degrees depending on temperature and the dynamic angle was about 10 degrees. One drawback with this method is that it is difficult to apply a uniform normal pressure on the contact area. Friction of rubber/ice is dependent on the normal pressure and therefore another method to measure friction was adopted.

A ring of rubber (ϕ=70mm) was vulcanized to a steel plate and compressed with a normal force N corresponding to a pressure of about 2 bars. The ring was subjected to an increasing torque Mv until the grip was lost. The friction coefficient was assumed proportional to the ratio between torque and normal force (Mv/N). This method has also been used in the field with some success. In figure 2 it is possible to see the trace of the rubber contact. Tests on cold ice (-10°C) resulted in a friction coefficient of μ=0.23 almost independent of used ice topography. It was however important that the rubber was in direct contact with solid ice. Small pieces of broken ice or frost could increase the friction substantially. Tests at warm ice (-4°C) were highly dependent on the ice topography. Smooth flooded ice showed the lowest values μ=0.1 and the ground ice gave consistently higher frictions μ=0.2. It was possible to relate the increasing friction coefficient to the number of contact points between ice and rubber.

4. Discussion

It is assumed that ice can be manufactured in the laboratory with consistent friction properties given that crystal shape and size is controlled by seeding and freezing temperature. A sufficient plane surface can be achieved with an ordinary planar tool made for wood. Temperature effects were strong on all ice surfaces but grinding or other mechanical treatment of the surface makes it possible to keep a higher friction at warm temperatures. This finding can be utilized to maintain a more constant tyre grip in field tests when the air temperature changes.