Dynamic Observation of Contact Behavior between Rubber for Tires and Ice by Refraction Contrast Imaging

Studded tires were abolished in 1994 due to environmental problems, such as dust and noise pollution, in Japan. In order to run on ice or snow safely, winter tires called studless tires have been developed and sold. In recent years, many studless tires are available in the market. Studless tires make the surface of an icy road very smooth when they slip on the road, resulting in an icy road with a very low friction coefficient. In addition, the friction between a studless tire and ice is related to the characteristics of the ice, e.g., the crystal structure, the size, the dielectric constant and the concentration of impurities [1,2]. Also, the frictional heat generated between a studless tire and an icy road dissolved the surface of the icy road, and water serves as a lubricant [3]. These friction behaviors become complex under the conditions of the boundary and the fluid lubrication. Nihei *et al.* have reported about the effects of the surface roughness of a studless tire [4]. According to their report, when the surface roughness was about 50 μm, the friction coefficient became maximum, and they expected that water is probably removed due to surface unevenness. Therefore, a systematic investigation and a detailed analysis of these behaviors are required to improve the performance of studless tires. In this study, we observed and investigated the contact behavior between the rubber for tires and ice.

The *in situ* observation of their behaviors by X-ray refraction contrast imaging caused by the reflection effect was carried out at the third hutch of beamline **BL19B2**. A continuous X-ray from the synchrotron radiation source was monochromatized to 20 keV by a Si(311) double crystal monochromator. In order to perform time-resolved observation, the X-ray detector adopted was a CCD camera with a pixel size of 10 μm (C4880, Hamamatsu Photonics K.K). The CCD camera was coupled with the optical lens and the phosphor screen. The distance between the sample and the X-ray CCD detector was determined to be about 2 m using the formula [5], $\Delta X = (\lambda L)^{1/2}$, where ΔX is the space resolution of detection, λ the X-ray wavelength, and L the distance from the sample to the detector. The beam diffuser made by rotating a sandpaper was installed at the first hutch in order to remove interference patterns, probably caused by Be windows. The compression-testing machine equipped with a high-precision cooling function was prepared (Fig. 1). Rubbers of different surface roughnesses were obtained using various kinds of sandpaper based on the JIS standard. The surface roughnesses of the rubbers were ~ 20 μm, ~ 45 μm, ~ 60 μm and ~ 90 μm. The rubbers prepared were of $2^l \times 15^w \times 3h^h$ mm^3. The X-ray refraction contrast imaging data was stored during the process of compressing the sample at a speed of 5 mm/min until the load reached 2 kg/cm^2.

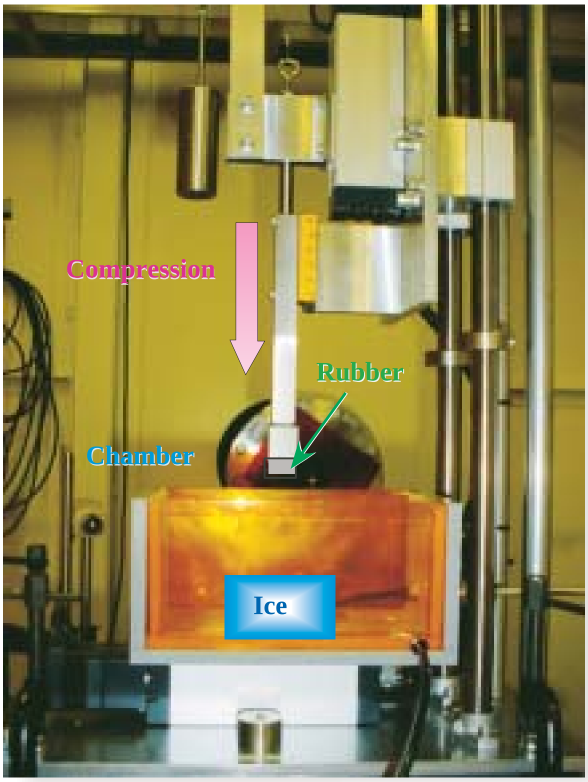

Fig. 1. Compression-testing machine equipped with a high-precision cooling function.

The images of the contact behavior between rubbers of different surface roughnesses and ice are shown in Fig. 2. When the surface roughness is about 20 µm, the rubber and ice are completely in contact, and there is almost no clearance. The dewatering effect could not be acquired at this surface roughness. As the surface roughness increases, the clearance increases due to surface unevenness, and then it seems that passages for dewatering would be formed. On the other hand, when the surface roughness is very large, the friction coefficient is small because of the drastic decrease in the contact area. Thus, it is very important to observe *in situ* contact behaviors between the rubbers and ice in order to improve the performance of studess tires.

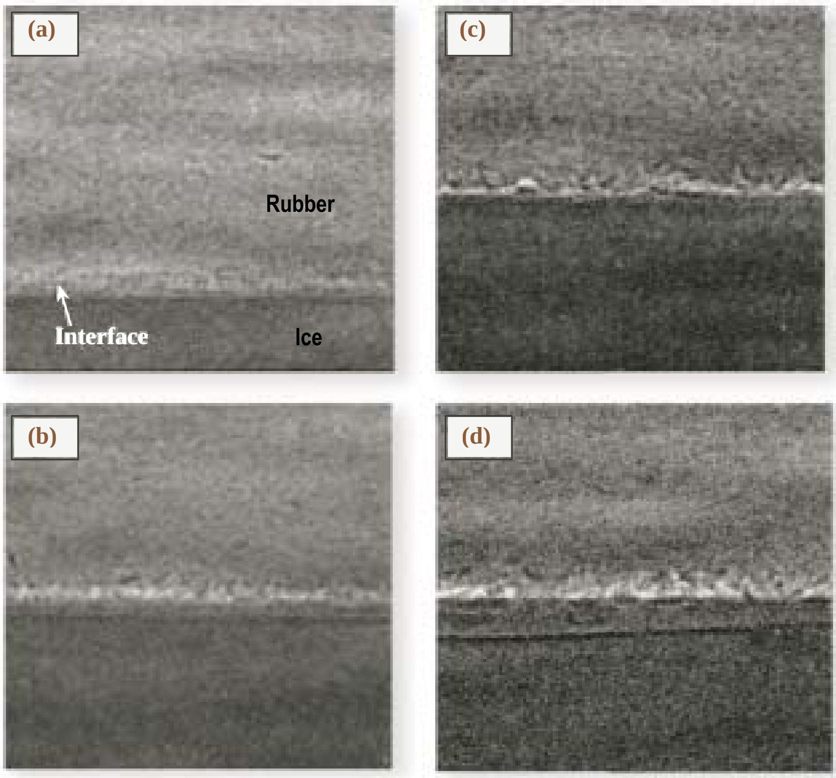

Fig. 2. X-ray refraction contrast images under the condition of ice and rubbers contact. The surface roughnesses of the rubbers are **(a)** 20 µm, **(b)** ~ 45 µm, **(c)** ~ 60 µm and **(d)** 90 µm.

Hiroyuki Kishimoto

Material & Process Technology Research Dept.,
SRI Research and Development Ltd.

E-mail: h-kishimoto.az@srigroup.co.jp

References

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