Effects of silica particles on the flow law of ice-silica mixtures: Its application to flow model of lobate debris aprons on Mars

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Some topographic features related to ice-dust mixtures are discovered on the surface of Mars. Particularly, lobate debris aprons, which can be seen in mid- to high-latitude regions, have the convex shape, so they have been interpreted as the result of viscous creep of ice-dust mixtures. Thus, the flow properties of ice-dust mixtures are important to study the formation process of such topographic features on Mars. Previous researchers made experimental studies of ice-dust mixtures to clarify the mechanical strength depending on the dust contents. However, we had difficulty assessing each results together, because they used the samples with different dust particle sizes, shapes, and internal structures etc., for each experiment. Therefore, in this study, we carried out deformation experiments of ice-silica mixtures by changing the silica contents with a same internal structure and a constant particle size to examine the flow laws for each sample, so that we studied the dependencies of silica contents and internal structures on the mechanical behavior.

We made the samples by mixing ice particles (0.3-1mm in the diameter) with silica glass beads (1micron in the diameter). The silica contents were 0, 1, 10, 30, and 50wt.%. We prepared the samples by using two methods to make different internal structures. One was a frozen sample method (f.s.) that we mixed ice grains, glass beads, and water in a mold. Another was a pressure-sintering method (p.s.s.) that we compressed the mixtures of ice grains and glass beads by using a piston at about 50MPa. All samples had a cylindrical shape. We conducted uniaxial compression tests under constant strain rates from 2.2x10^{-6} to 2.9x$10^{-3}$$s^{-1}$ in a cold room at 263K.

We examine the flow law ($de/dt=As^n$: de/dt is the strain rate, s is the maximum stress, and A and n are the flow parameters) of each sample with different silica contents and internal structures, where the flow law was the relationships between the maximum stress and the strain rate on each stress-strain curve. As a result, we clarified that the flow law varied with the silica contents and the internal structures systematically. Particularly, the power index, n, increased with the silica contents : the n of f.s. with the contents of 50wt.%, was twice as large as that of pure ice., and the n of p.s.s. was 3.5 times larger than that of pure ice. In addition, in this range of the strain rates, the maximum stress of f.s. was larger than that of p.s.s. : the stress of f.s. was 1.5-3 times stronger than that of p.s.s. at the strain rate of $10^{-4}$$s^{-1}$ in the case of 10-50wt.%.

We compared our results with the previous works (Hooke *et al.*, 1972; Durham *et al.*, 1992), which studied the relationship between the solid particle contents and the strength. As a result, our results were consistent with their results qualitatively, and the quantitative difference could be caused by the relationships depending on the strain rates. In addition, we found that the complicated behavior of the relationships observed in the previous works could be caused by the power index, n, depending on the contents.

Finally, we applied our results to the flow models of lobate debris aprons referred to Mangold and Allemand (2001). They calculated the shapes by using the model with the power index, n, and compared their results with the observed morphological data (MOLA). They calculated only two cases, pure ice (n=3) and perfectly plastic ice (n=infinite), and concluded that the shape of perfectly plastic ice was more consistent with the observed data. We found that the results with larger silica contents became closer to the observed data, and particularly, the calculated shape for the p.s.s. with the contents of 50wt.% was almost consistent with the MOLA data.