Experimental study on the effect of filling factor and internal structure of sintered porous materials on their mechanical properties

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Planets are thought to have formed by collisions between planetesimals. For collisions in the strength-dominated regime, the filling factor and tensile strength of planetesimals are important parameters that determine the collision outcome (Jutzi et al., 2010). The filling factor of the planetesimal is considered to have been increased by the sintering process during the thermal evolution (e.g., Gail et al., 2015). The formation of inter-particle necks by sintering changes the mechanical properties of the granular material (Poppe, 2003). Therefore, an understanding of the mechanical properties of sintered porous materials in relation to their internal structure and filling factor is necessary to elucidate the physical phenomena associated with planetesimals and porous primitive bodies. In this study, we prepared sintered samples with different filling factors. We investigated the changes in the mechanical properties of the sintered samples, in particular longitudinal wave velocity and bending strength, with the filling factor.

We used four types of soda-lime glass particles with a softening point of 730℃: monodisperse and spherical glass beads with a median diameter of 94 μm, monodisperse and spherical glass beads with a median diameter of 55 μm, polydisperse and spherical glass beads with a median diameter of 22 μm, and polydisperse and irregularly shaped glass powder with a median diameter of 34 μm. We heated these particles in an oven at 620-650℃ and prepared sintered samples. Electron microscopy images show that heating at temperatures near the melting point of irregularly shaped particles not only forms necks between the particles but also changes the particle morphology by rounding the corners and smoothing the surface. The filling factor, longitudinal wave velocity, and bending strength of these samples were measured.

We show that the longitudinal wave velocity of the sintered glass particles increases in proportion to the filling factor, irrespective of the particle size, particle size distribution, initial internal structure, and particle shape. The increasing trend observed in this study is similar to that observed in the measurement of sintered ice aggregates (Shimaki and Arakawa, 2021) and Greenland snow (Smith, 1965). The bending strength of the sintered samples increases according to two trends. One is a power law increase, which is consistent with the measured tensile strength of sintered ice aggregate (Shimaki and Arakawa, 2021). The other is a sharp increase in a narrow range of the filling factor, which is not observed in sintered ice aggregates. This increase asymptotically approaches the power-law increase with increasing filling factor. The latter increase in strength is mainly due to neck growth between particles, while the former is thought to be due to changes in particles alignment.