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Thermal Properties of Granular Materials on Planetary Surface

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Understanding of thermal conductivity of granular materials is a key in considering situations of planetary surface. For example, regolith, which is expected to have low thermal conductivity because of high porosity, works as a blanket to protect subsurface material from external thermal disturbance. The conductivity sensitively depends on the amount of vacant space between grains. Thermal inertia as well is an important parameter to characterize the surface material by remote sensing. It is believed to depend primarily on grain size. In this presentation we report an experimental approach to characterize thermal properties such as conductivity, diffusivity and thermal inertia of granular material.

To characterize the state in this research the following parameters are important; grain porosity, packing porosity and bulk density. The bulk density is given by mass over total volume(grains and space). Packing porosity is given by fractional volume of vacant space between grains over total volume. When we pour granular materials from above under gravity, sedimentation and tapping would result in a state of random loose packing. The amount of vacant space depends on the size distribution of the grains. In case of monodisperse system this would be around 0.38. Grain porosity is given by fractional vacant space inside the grain. When we consider granular materials of volcanic origin this sometimes reaches as high as 0.7. The bulk density is given by the combination of other two parameters.

In this work, we measured packing porosity, bulk density and thermal conductivity of granular materials to bring out the relationship between structure and thermal properties. Measured samples are glass beads,porous glass beads,sands,pumice from Towada volcano and scoria from IzuOhshima. Scoria and pumice are sieved so that the measurements are conducted on the sample with homegeneous grain size. The average grain size ranges from 30 micron to 6 mm. One of the remarkable result is that bulk density definitely controls thermal conductivity; the smaller the bulk density, the smaller the thermal conductivity irrespective of packing porosity and grain porosity. All the data can be fitted by a universal line such as $k = 0.12d + 0.070$; where k is thermal conductivity in W/mK, d is bulk density in g/cm^3. We derived this equation from the data on bulk density in the range of 0.2 - 1.6 g/cm^3. We discuss how this universal relationship can be applied to the case of Mars. Most of the data to determination this relationship in for the samples with homogeneous grain size. We also discuss how the polydisperse system is consistently understood by this universal relationship.Analysing the results of the measurement, we propose a new relationship among packing porosity, particle size, thermal conductivity, thermal diffusivity and thermal inertia.