A simple method for the distinction of different combinations of grain size and porosity under Martian atmospheric pressure

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Abstract
We propose that the variation of the bulk thermal conductivity under different Martian pressure (500 – 1000 Pa) can be important information to distinguish different combinations of grain size and porosity. We measured the thermal conductivities of glass beads, natural pyroclasts and hollow glass beads under Martian atmospheric pressure. We found that the ratio of the thermal conductivity under Martian atmospheric pressure to under atmospheric pressure (1013 hPa) mainly depends on the grain size.

1. Introduction
Thermophysical properties of Martian regolith are important clues to understand the surface geology. To characterize the surface materials by remote sensing, thermal inertia is used as an important parameter [1, 2]. Thermal inertia is defined by thermal conductivity, bulk density and specific heat capacity. Especially thermal conductivity strongly affects on thermal inertia [3]. Therefore, understanding of thermal conductivity of granular materials is a key in considering situations of planetary surfaces.

The bulk thermal conductivity of granular materials under Martian conditions around 6 hPa is quite sensitive to variations in grain size [4]. There are many studies on laboratory experiments for the thermal conductivity of both spherical glass beads and natural soils [e.g. 4, 5, 6]. Theoretical models also reproduced the bulk thermal conductivity measured in the laboratory [3, 7].

Porosity of the surface layer also affects the bulk thermal conductivity under Martian atmospheric pressure, although the grain size plays important roll. Surface layers that have different combinations of grain size and porosity could have same values of the bulk thermal conductivity.

In this paper, we will show a basic idea to distinguish different combinations of grain size and porosity with in-situ measurements. We measured the thermal conductivities of glass beads, natural pyroclasts and hollow glass beads under Martian atmospheric pressure. We found that the variation of the bulk thermal conductivity under different Martian pressure (500 – 1000 Pa) could be important information to distinguish different combinations of grain size and porosity.

2. Method
To measure the thermal conductivity of the granular materials under Martian atmospheric pressure, we used a measurement device in a vacuum chamber. Inside the measurement device, there is a nichrome wire as a heater and a chromel-alnem thermocouple as a thermometer. So-called line heat method [8] is used to measure the bulk thermal conductivity of the sample.

We selected samples for two points of view: a pair of samples that have same size and different porosity, a pair of samples that have same porosity and different size. Table 1 shows the samples we used in this study.

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Sample origin</th>
<th>Size (average) in μm</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass beads</td>
<td>Boronic-silicate glass beads</td>
<td>37 – 63 (50)</td>
<td>0.427</td>
</tr>
<tr>
<td>Q-CEL 7040S</td>
<td>Sodium boronic-silicate glass beads</td>
<td>5-90 (45)</td>
<td>0.879</td>
</tr>
<tr>
<td>23A4C</td>
<td>Hachinohe pyroclastic flow deposit</td>
<td>1000-4000</td>
<td>0.893</td>
</tr>
<tr>
<td>Mt. Fuji</td>
<td>Pyroclastic fall deposit of Hoei eruption</td>
<td>1000-4000</td>
<td>0.739</td>
</tr>
</tbody>
</table>
5. Results

Figure 1 and 2 shows the result of our measurements. We couldn’t distinguish 23A4C (grain size: large, porosity: large) from glass beads (grain size: small, porosity: small) with the absolute value of the thermal conductivity at 1000 Pa (Figure 1). However, those samples have different value of the normalized thermal inertia at 1000 Pa (Figure 2).

![Figure 1: Thermal conductivity as a function of pressure. The pairs of glass beads and natural products have the same size respectively. The samples represented in blue and green plots have the same bulk porosity.](image1)

![Figure 2: Normalized thermal conductivity under low pressures. The pairs of glass beads and natural products have the same size respectively. The samples represented in blue and green plots have the same bulk porosity.](image2)

6. Discussion

As we mentioned in the introduction, thermal inertia is used as an important parameter to characterize Martian surface materials by remote sensing [2] and is strongly affected by thermal conductivity [3].

Continuous observations of temperature of the Martian surface revealed the seasonal variation of the value of the thermal inertia [9]. Although surfaces with horizontal or vertical heterogeneity may yield apparent thermal inertia which varies with time of day and season [9], the origin of the variation is not completely understood.

The variation of the thermal conductivity under Martian atmospheric pressure could be responsible for the seasonal variation of the thermal inertia of Martian surface. Martian atmospheric pressure seasonally varies between 600 and 1000 Pa. Under this environment, the bulk thermal conductivity can vary with a factor of 2.

The seasonal variation of the thermal inertia could be used to distinguish different combinations of grain size and porosity if it is caused by the variation of the thermal conductivity under different atmospheric pressure. The results of the thermal observations by both orbiters and landers should be re-investigated with this point of view.

7. Summary and Conclusions

The ratio of the thermal conductivity under Martian atmospheric pressure to under atmospheric pressure (1013 hPa) mainly depends on the grain size. The normalized thermal conductivity of granular material could be a simple tool to distinguish different combinations of grain size and porosity under Martian atmospheric pressure. The seasonal variation of the thermal inertia could be used to distinguish different combinations of grain size and porosity if it is caused by the variation of the thermal conductivity under different atmospheric pressure.

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References


