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Non-contact measurement for thermal inertia of particle beds

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Abstract

This paper aims to 1) measure the equivalent values of the "thermal inertia" of particle beds directly, and 2) compare the values with the results of the conventional calculation for thermal inertia. We directly measured the thermal inertia of several volcanic deposits, and found that the thermal inertia of some samples could be different from the results of conventional calculation for thermal inertia. We need more consideration about the mathematical expression of the thermal inertia of particle bed.

1. Introduction

The thermal inertia is a physical property that controls the diurnal and seasonal cycles in surface temperature of planets. It is defined as a function of thermal conductivity, heat capacity, and density, all of which depend primarily on the physical structure of the surface layer.

Usually, the thermal inertia of particle bed has been calculated as the product of thermal conductivity (experimental data), bulk density (experimental data) and heat capacity of particle bed (literature values of the material) [e.g. 2]. This estimate is valid as far as the target material is uniform and made up of single phase. The validity of the formula ($I = \sqrt{k\rho C}$) is not evident for the particle bed or vesiculated materials, because the estimate assumes continuum. We need more considerations about the mathematical expression of the thermal inertia of particle bed.

This paper aims to 1) measure the equivalent values of the "thermal inertia" of particle beds directly, and 2) compare the values with the results of conventional calculation for thermal inertia.

2. Method

2.1. Direct determination of thermal inertia

Buettner (1951) [1] proposed the mathematical analysis of non-penetrating constant heat flow, in which constant radiant heat is absorbed by the upper surface. Using *Buettner's* mathematical expression, we can determine the equivalent value of thermal inertia by observing temporal variations of the surface temperature of particle beds. Under a certain condition, the surface temperature of the particle bed is given by

$$T_S - T_0 = \frac{2Q}{I}\sqrt{\frac{t}{\pi}} \quad (1)$$

in which T_s = surface temperature, T_0 = initial surface temperature, Q = heat supply minus heat loss to the environment by radiation, convection and evaporation, I = thermal inertia, and t = elapsed time.

2.2. Samples

We determined the thermal inertia of several volcanic deposits. You will find the samples we used in Table 1.

Table 1: Samples of volcanic deposits

Sample name	Material	Thermal conductivity @ 1 atm	Porosity
D1 (Izu-Oshima, 1986 eruption)	Pyroclastic falld deposit	0.13 – 0.27	0.47 – 0.79
D1 under (Izu-Oshima)	Aeolian wash bed origin	0.24	0.47 – 0.51
23A4C (Towada, eruption 5400 y.a.)	Pyroclastic fall deposit	0.11 – 0.19	0.59 – 0.89

3. Results

Figure 1 shows the results of our measurement. Dark-colored-dots show the results of direct determination of thermal inertia, and light-colored-dots show the results of calculations for thermal inertia using separated values of thermal conductivity, bulk density, and heat capacity of particle beds.

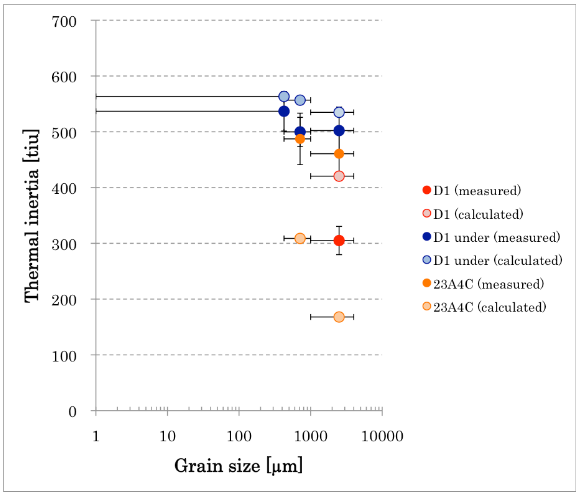

Figure 1: Thermal inertia of volcanic deposits.

4. Discussions

We had almost same value for the thermal inertia of "D1", which has relatively homogeneous grains size and high-porosity. On the other hand, we had significant differences of the thermal inertia for "D1 under" and "23A4C" between directly determined and conventionally calculated values.

High-porosity of "D1 under" and "23A4C" possibly affects the equivalent value of thermal inertia. We want to note that "23A4C" is more vesiculated than "D1 under". The difference of grain porosity (vacant space in grain) might yield the difference of thermal property. The volumetric heat capacity ($=\rho C$) of the particle bed could be different from the simple product of bulk density and heat capacity, because the heat is transported through both gaps between grains (convection) and grain contacts (conduction). We have to consider both convection and conduction heat transfer to evaluate the volumetric heat capacity of granular materials. To understand the surface property of planetary soils using thermal inertia, the formula ($I = \sqrt{k\rho C}$) should be treated carefully for particle beds.

5. Summary and Conclusions

We directly measured the thermal inertia of several volcanic deposits. We found that the thermal inertia of some samples could be different from the results of the conventional calculation for thermal inertia. We need more consideration about the mathematical expression of the thermal inertia of particle bed.

References

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[2] Mellon, M. T., Fergason, R. L., Putzig, N. E.: The thermal inertia of the surface of Mars, The Martian Surface: Composition, Mineralogy, and Physical properties, Cambridge University Press, pp. 399-426, 2008.