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The “Guarded Torus" approach for MUPUS thermal properties measurements

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Abstract

In the past few years scientists developed an increasing interest in the structure and behaviour of extraterrestrial surfaces. Comets are playing a main role as targets of these investigations. They are composed of ice, dust and organics and it is assumed that comets consist of the basic material out of which the solar system was formed. The properties at the surface and the upper layers of comets as well as their change during the approach to the sun are therefore of special interest. The thermal and mechanical properties of the comet 67P/Churyumov-Gerasimenko and their changes should be measured with the MUPUS-probe, one of the instruments on the *Rosetta* lander *Philae*. The “Guarded Torus” approach is a possible way of optimizing the scientific results of the thermal conductivity measurements with MUPUS like sensors.

1. Introduction

The so-called *Guarded Torus* (*GT*) method [2] is a non-conventional method especially for probes consisting of several sensors like MUPUS. The general measurement principle is the same as for *Line Heat Source* (*LHS*) sensors [1]. However, aimed at the usage of sensors which are more feasible from the point of technological implementation and increasing the scientific return in the case of non-homogeneous layered media. As for *LHS*-sensors, the thermal conductivity is obtained by a temperature measurement at the sensor at two points in time. The difference to the *LHS*-method, where only one segment is heated, is that in case of the *GT*-method a heated cylinder sensor of finite dimension is supported by two similar guard heaters placed directly above and below the main sensor. The use of those additional heaters minimizes the vertical heat flux, generated by activating the main heater, and leads therefore to the behavior of the sensor similar to a classical *LHS*-sensor.

2. The GT-sensor measurements

The *GT*-sensor used for the first measurements done at the DLR consists of 3 segments each 3.5 cm long with a resistance of about 36 Ω at room temperature. The heating foil is fixed on a full aluminum cylinder with a diameter of 1 cm.

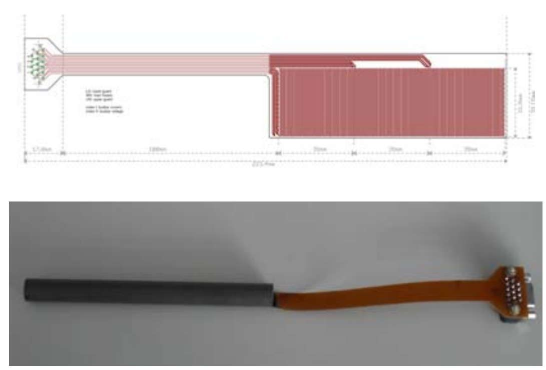

Figure 1: Design of the first *GT*-prototype.

Several measurements with compact, porous and granular media under atmospheric pressure and in vacuum were done. The thermal conductivity λ is inversely proportional to the temperature increase measured and can be obtained without information on the density or the heat capacity of the sample material. The temperature curves look similar to those measured with a *LHS*-sensor (see for example Figure 2). However, in case of heating only the main heater in the middle of the sensor the values for the thermal conductivity are about three times as high the certified ones.

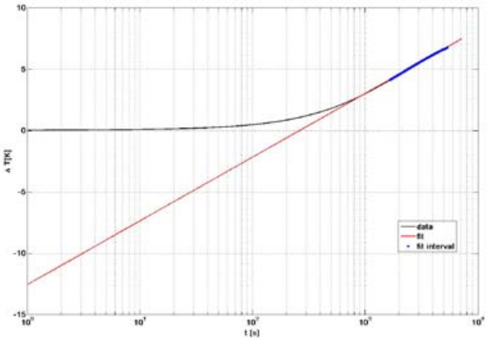

Figure 2: Temperature versus time obtained by the middle *GT*-sensor for Rohacell hard foam in case only the main heater is active.

Increasing the heating power of the upper and lower guard leads to a refinement of the thermal conductivity results. For a *GT*-sensor with the above mentioned geometry the best results were obtained by heating the guards with 1.2 times the power of the main heater.

4. GT simulations

In addition to the measurements models also concerning the specific heat, density, contact resistance and porosity of the material were calculated. The results from the simulation are compared with the measurement. This allows a more precise specification of the thermal parameters of the various materials. Figure 3 shows the temperature distribution inside a cylindrical PVC block. In this case only the main heater of the GT is active.

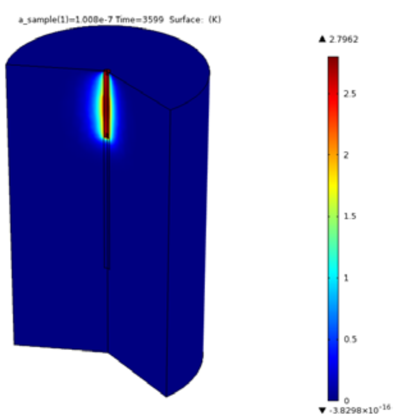

Figure 3: Simulation of the temperature distribution inside a PVC block during a *GT* measurement.

5. Summary and Conclusions

The *GT* method is a modification of the *LHS* method that allows utilizing sensors with a different geometry suitable to resolve variations of thermal conductivity as a function of depth, while still retaining the advantages of the *LHS* method. Good matching between simulations and measurements of certified materials will allow a more precise identification of thermal properties of layered materials as expected to be found on the cometary surface. The *GT* method will allow an optimized power supply for MUPUS like sensors.

Acknowledgements

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