A Simple Method for Thermal Characterization of Low-Melting Temperature Phase Change Materials (PCMs)

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Introduction: We present a method for the characterization of the thermal parameters of PCMs, dedicated for cold storage applications. It consists of a cyclic cooling and heating of the PCM sample placed into a holder tube and a monitoring of the temperature field evolution. Temperatures are applied on both sides of the tube and the PCM (T_1 and T_2).

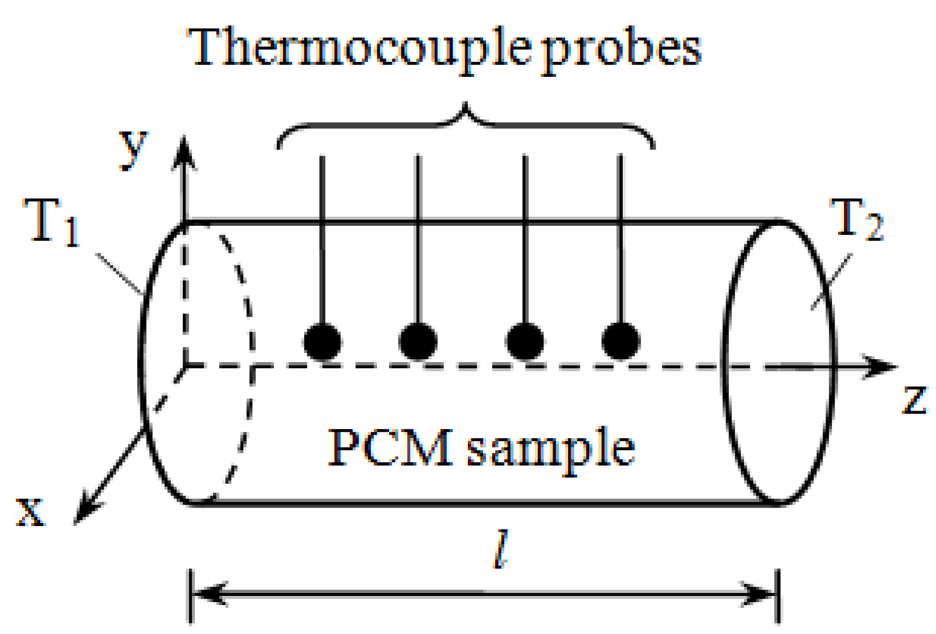

Figure 1. Schematic of the experimental setup

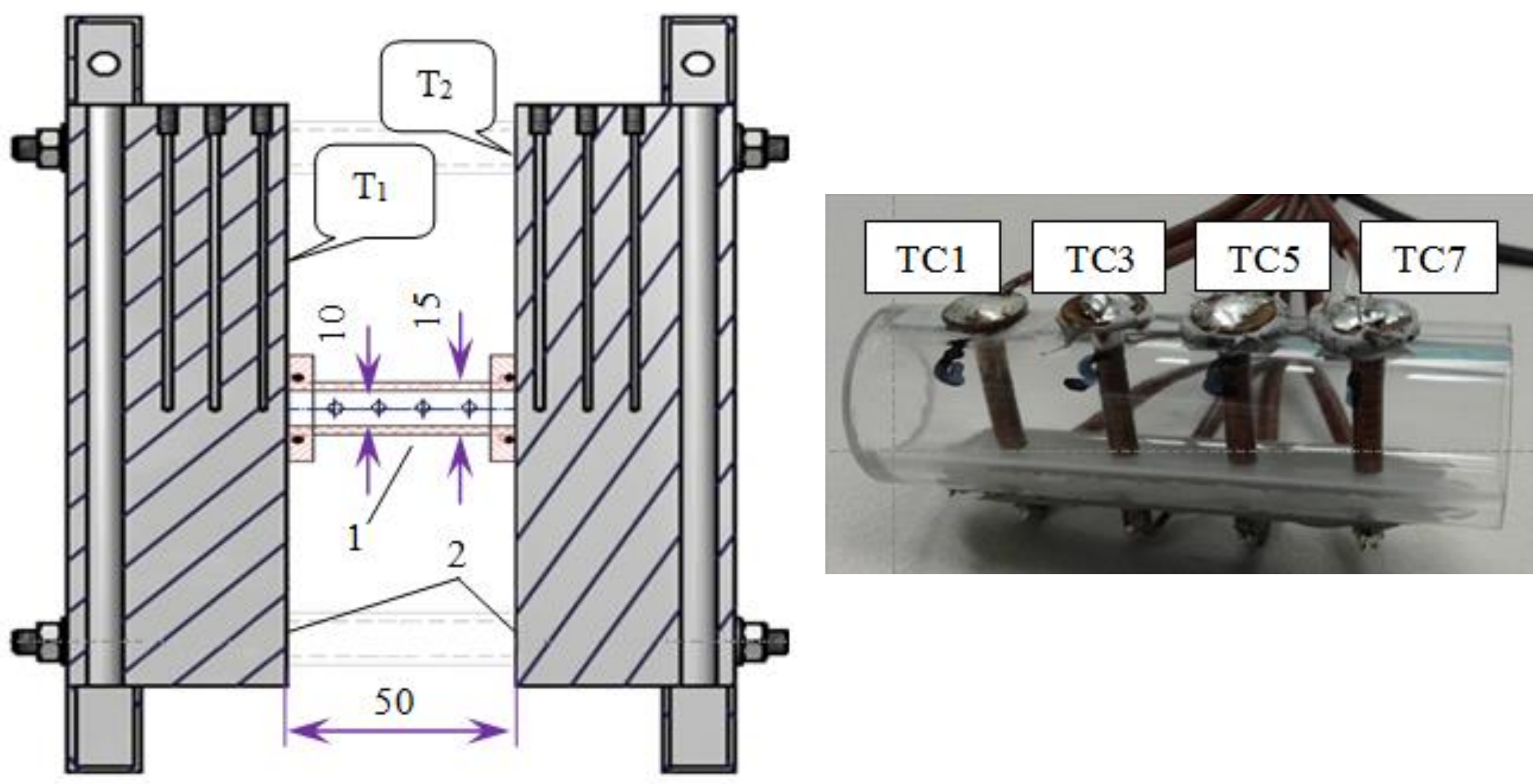

Figure 2. Setup (1: tube holder, 2: aluminium blocks)

We then use an inverse problem to define the thermal parameters (such as latent heat of fusion, thermal conductivity, specific heat in solid and liquid states) from experimental measurements.

Inverse problem: estimate the vector of parameters **Y** with the minimization of the difference between the measured variation **U** of temperature with time at N_p selected points of the PCM sample and its theoretical values **T**, obtained by solving the direct problem [1]:

$$\Delta(\mathbf{Y}) = [\mathbf{T}(\mathbf{Y}) - \mathbf{U}]^T [\mathbf{T}(\mathbf{Y}) - \mathbf{U}] \xrightarrow{\mathbf{Y}} \min$$

In matric form, the necessary minimum condition is, with **Z**, the sensitivity coefficients matrix:

$$\mathbf{Z}^T(\mathbf{Y})[\mathbf{T}(\mathbf{Y}) - \mathbf{U}] = 0 \qquad Z_{ij}^{(k)} = \frac{\partial T_i^{(k)}}{\partial Y_j}$$

It can be calculated with the numerical models by solving the *direct* problem and they determine how the Y_j thermal parameter affects the temperature in the *i*-th selected points of the PCM sample at the *k*-th moment. The solution of the inverse problem can be found using the so-called *sensitivity coefficients iterative method* [1].

Numerical results: we use a simplified approximation, in which the heat transfer in the PCM is dominated by conduction. The PCM is distilled water.

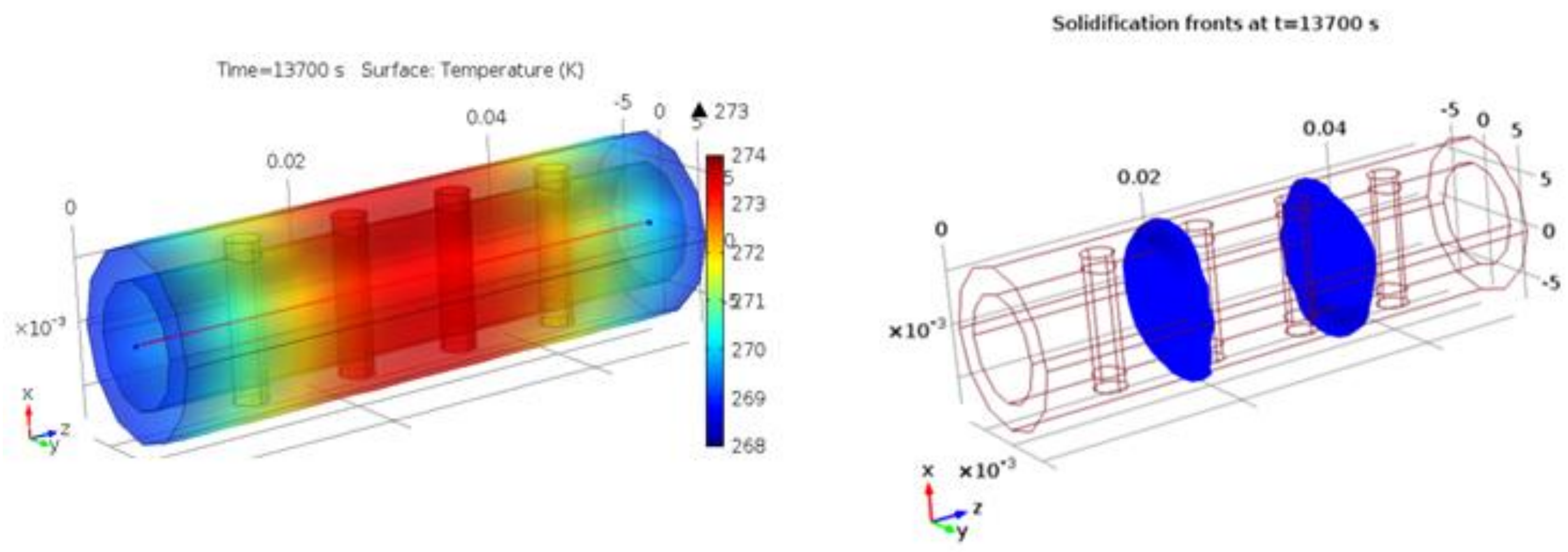

Figure 3. Temperature field and solidification fronts at 13700s

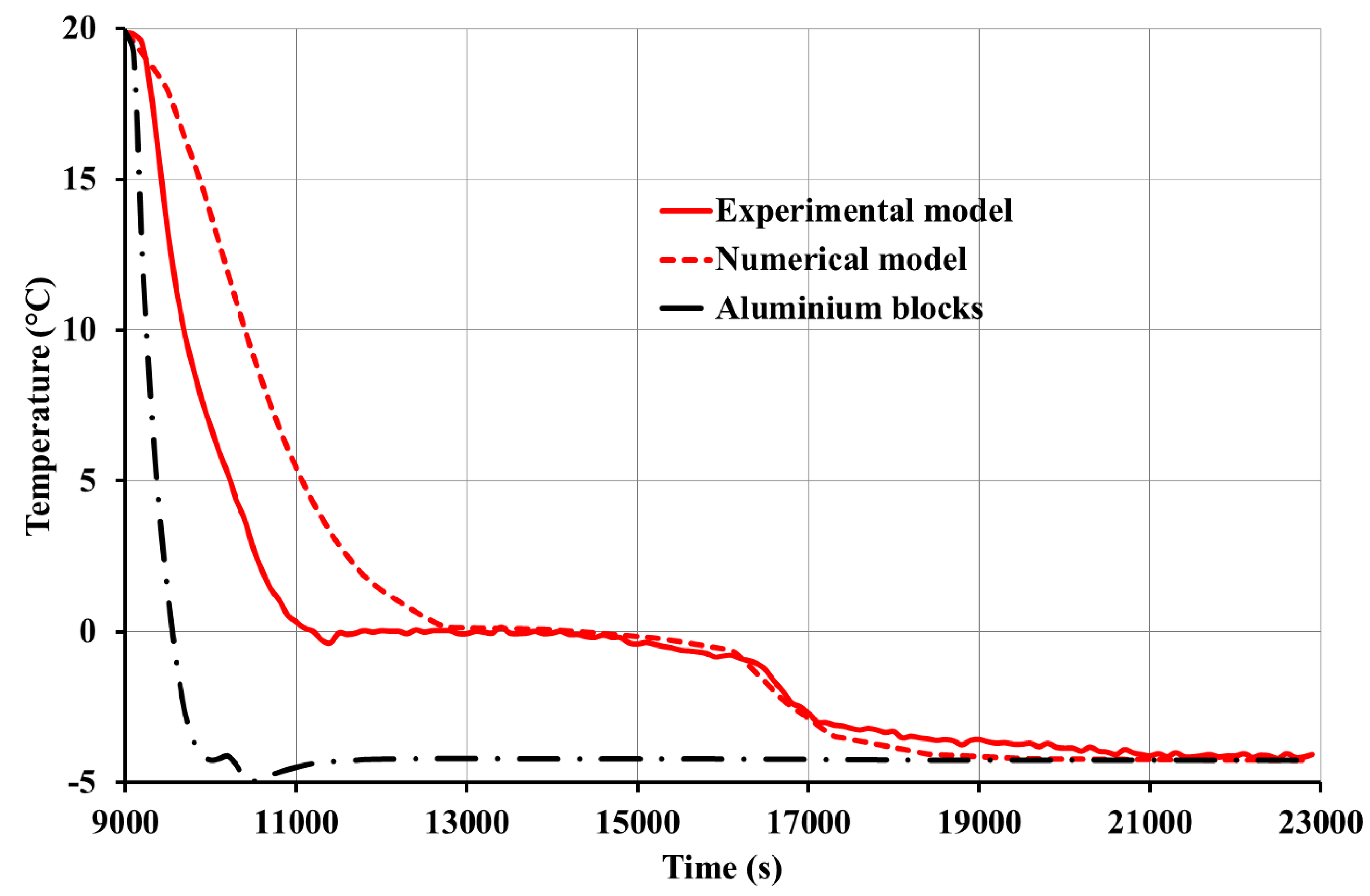

Figure 4. Temperature evolution at TC3

Figure 5. Sensitivity coefficient Z at TC3 when latent heat is perturbed by 10%

Conclusions: In this work, we use the COMSOL Multiphysics® software to investigate the temperature history of the PCM sample, as well as its sensitivity to the variations of the PCM's thermal parameters. An experimental setup involving this approach has been designed, assembled and tested. Some intermediate results have been reported and discussed.

References:

1. A. Wawrzynek, M. Bartoszek, Inverse heat transfer analyses as a tool of material parameter estimation, *Proceedings of conf. Thermo-physics* 2006, 03-19, 2006
2. COMSOL 5.2, Heat Transfer Module User's Guide.