UNCERTAINTIES IN MEASUREMENT OF THERMAL TECHNICAL CHARACTERISTICS OF BUILDING INSULATIONS

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Thermal technical standards in civil engineering force the evaluation of both thermal insulation and thermal accumulation properties of insulation layers, based on the numerical analysis of the heat transfer equation, supplied with boundary and initial conditions, with (at least) 2 constant characteristics λ and ζ: λ is the heat conduction factor and $\zeta = c\rho$ where ρ denotes the material density and c the thermal capacity. The reliability of such computational results depends strongly on the accuracy of setting both λ and ζ, based on the measurement (from 2 independent sensors) of the evolution of temperature $T(t)$ in time t, in practice $T_i = T(t_i)$ in s discrete times t_i, $i \in \{1, \ldots, s\}$, in the rather simple (nearly one-dimensional) equipment, consisting of 2 aluminium plates, insulated from the outer environment by 2 massive blocks of foam polystyrene: one plates generates the heat (per length) r_i, the material sample is located between both plates.

To obtain λ and ζ, it is necessary to solve certain inverse problem to the standard heat transfer one. The numerical analysis, based on the method of discretization in time and on the spectral analysis of ordinary differential operators, results in the direct evaluation of temperatures $\widetilde{T}_i$ as functions of 2 parameters λ and ζ, especially at the positions of both sensors. The parameters λ and ζ can be consequently identified, making use of the minimization of the sum of $(T_i - \widetilde{T}_i)^2$ over $i \in \{1, \ldots, s\}$ (related to both sensors), applying the Newton least-squares fitting.

The errors in the above sketched calculations have 2 principal sources: i) the real process of heat propagation does not satisfy the linearized one-dimensional equations (with constant coefficients) exactly, ii) the quantities r_i and T_i suffer from uncertainties of their setting or measurement. The first source cannot be removed, only reduced by the careful arrangement of the experiment (e. g. for macroscopically anisotropic materials 2 material characteristics λ and ζ are insufficient). The second source motivates the analysis of uncertainties of λ and ζ as functions of uncertainties of r_i and T_i, considered as uncorrelated. The results from statistics (namely the central limit theorem) justify the application of Gaussian probability distributions; such analysis uses typically the same algebraic manipulations as the Newton least-squares approach.

The contribution includes the presentation of the new MATLAB-based software and its application to the original ecological insulation materials, making use of the wood waste, designed and tested at the Faculty of Civil Engineering of the Brno University of Technology, too.