A new method of evaluation of thermal parameters of textile materials

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The investigations concern the evaluation of thermal parameters, such as thermal conductivity and capacity of textile materials. In the research, one side of a nonwoven sample, which has a rectangular shape was heated (Fig. 1). The thermal process was transient, and the temperature evolution was measured by the thermographic camera. Temperature maps were captured on the both sides of the measured sample to evaluate the cross-sectional thermal conductivity. The simultaneous measurement on both sides was done a using a set two mirrors and the measured material in between them. The presented investigations can be effectively used for evaluation of anisotropic, intelligent textile materials.

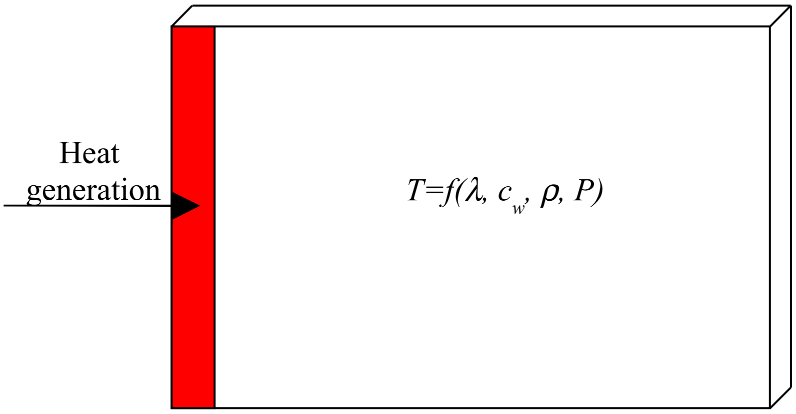

Fig. 1. A textile material sample heated on one side

The exemplary thermal images are presented in Fig. 2. A nonwoven with phase change (PCM) was used in the research, and the results were compared with typical textile material. Both sides on the materials were investigated both in heating or cooling process.

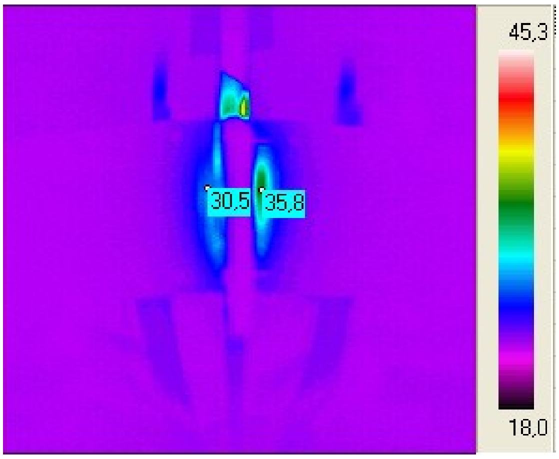

Fig.1 Thermogram of nonwoven without PCM at 355 second of heating

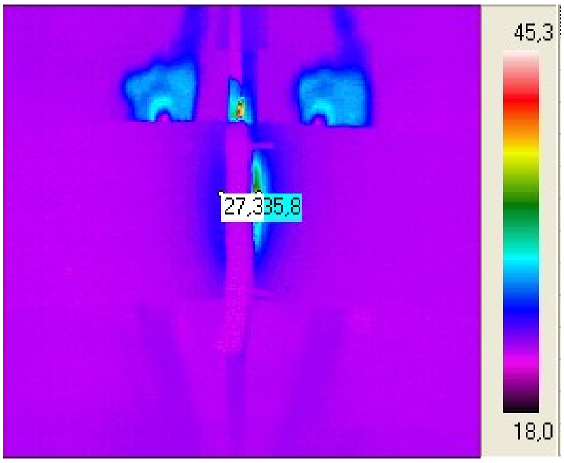

Fig.2 Thermogram of nonwoven with PCM at 355 second of heating

At first, in order to evaluate the thermal parameters of a nonwoven, the thermal modeling was carried out for the materials with known thermal coefficients. The forward and inverse heat transfer problems were taken into account. A sample had rectangular shape with the width much smaller than its length (Fig. 1). An impulse of thermal energy was delivered to the material, and temperature distribution was calculated using 3D thermal model, as below.

$$\frac{\partial}{\partial x}\left(\lambda\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\lambda\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(\lambda\frac{\partial T}{\partial z}\right)+q_v=c_w\rho\frac{\partial T}{\partial t}$$

It was assumed that thermal conductivity is varying and depends on the direction in the material. Typically, the conductivity in cross-sectional direction is higher than in longitudinal one. In the forward problem, assuming the values for thermal conductivity (λ), specific heat (c_w) and density (ρ), for a given power (P) delivered for the sample, the temperature distribution $T = f(P)$ is calculated.

Then, in the inverse problem, for a given power and measured temperature distribution on both sides of the sample, λ, c_w and ρ are evaluated. The boundary conditions as the natural convection were assumed.

In order to solve the described problem, the optimization procedure (inverse problem) was applied using MATLAB® solver, including the thermal model of a sample in ANSYS® package (forward problem) – Fig. 3. The program in MATLAB called the ANSYS model in an iterative loop until the temperature values in the chosen places on the sample obtained from the calculations and measurements were not matched with a given error.

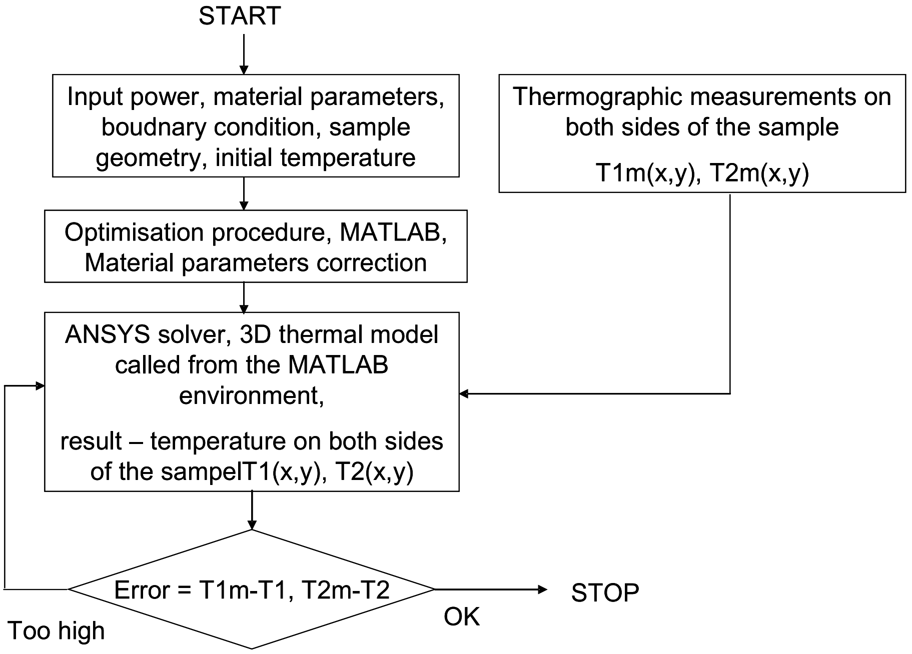

Fig. 3. Block diagram of the algorithm

References

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