Modelling of the Wool Textile Finishing Processes

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Abstract

Introduction: Within wool textile industries, a very important role is played by the so-called finishing processes, in which the textile substrate undergoes steam treatments to achieve the desired level of stabilisation and appearance [1]. The use of saturated steam represents the common denominator of such treatments but with variable values of temperature and pressure. Process parameters, namely temperature and moisture content, are known only at the beginning of the process but not in the textile material being treated, where the actual physicochemical effects takes place.
Use of COMSOL Multiphysics®: The application of existing mathematical models [2, 3] has been of fundamental importance to accurately describe the system behaviour and its kinetics. The use of 1D and 2D models based on Darcy's Law and Heat Transfer in Porous media allowed to assume the textile substrate as a porous media, with different properties mainly depending on the type of fibre and on the geometry of the system. Some physical and empirical correlations (e.g. equilibrium between water vapour humidity and moisture content in the fibre, heat released by the fibre when absorbing humidity) have been manually implemented in the models.
Results: Temperature and moisture content of a 50 mm layer of textile material in contact with steam at 100°C were evaluated during time dependent simulations, showing the presence of an initial transition phase when the steam flow passes through the material (Figure 1). The fibre temperature rapidly reaches values higher than the steam one, due to the heat of moisture sorption, whereas the moisture content increases very slowly, demonstrating that the diffusion coefficient of water molecules into the fibre is the limiting factor of the whole process (Figure 2).
Conclusions: The study has brought to valuable results, validated by experimental data carried out in a bench scale equipment. Under a scientific point of view, the devising of new and more complete models will be of fundamental importance to accurately validate the process steps and develop new diagnostic methods for industrial applications.

Reference

[1] R. Postle et al., The mechanics of wool structures, Halsted Press, Chichester, (1988).
[2] C.V. Le, et al., Heat and mass transfer in the condensing flow of steam through an absorbing fibrous medium, International Journal of Heat and Mass Transfer, vol. 38, pp 81-89, (1995).
[3] C.V. Le, Heat and mass transfer during forced convection of steam through fibrous assemblies, Ph.D. Thesis, The University of New South Wales, Kensington, NSW (1993).

Figures used in the abstract

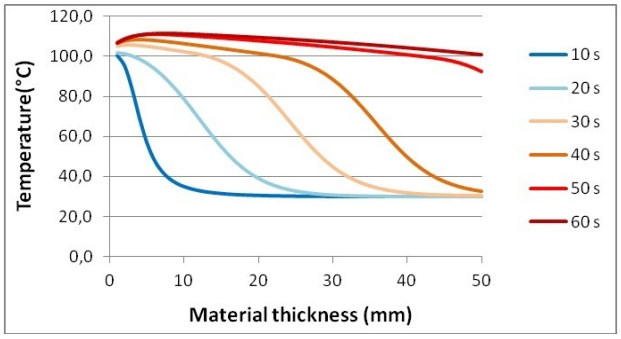

Figure 1: Evolution of the temperature through the thickness of the textile material during the initial transition phase of the process.

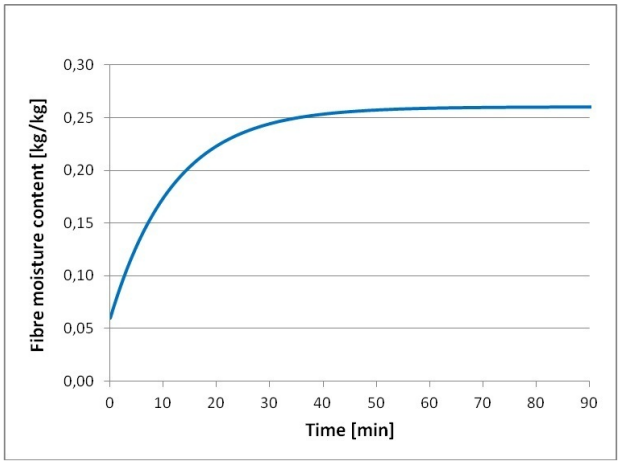

Figure 2: Evolution of the moisture content in the wool fibre for a pre-conditioned (7% initial moisture content) textile material.