

Modelling of the Wool Textile Finishing Processes

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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. A schematic view of the system can be seen in Figure 1.

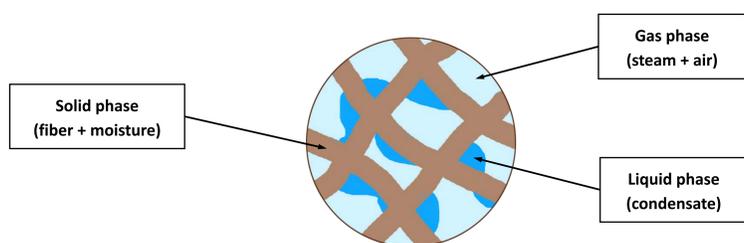


Figure 1. View of the multiphase system

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.

Computational Methods

The use of 1D and 2D models based on Darcy's Law, Heat Transfer in Porous media and Reacting Flow in Porous Media allowed to assume the textile substrate as a porous media.

The multiphase system showed in Figure 1 has been simplified into a two-phase system considering that the liquid phase (condensate) is present only in the early stage of the process and rapidly disappears.

Due to its structure, the moisture absorption profile in the wool fiber can be considered almost constant, except for the fiber surface which generates the highest resistance (Figure 2).

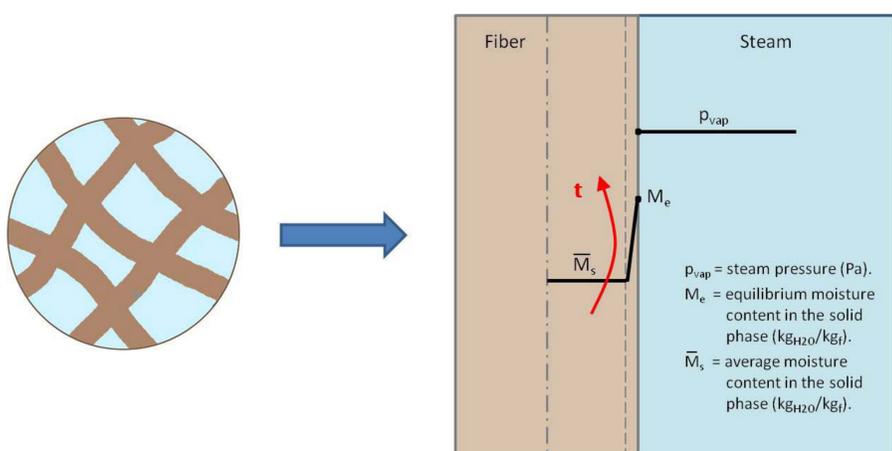


Figure 2. Wool fiber moisture absorption profile

Energy and mass transfer equations as well as continuity equations have been used both for the solid and the gas phases, whereas some physical and empirical correlations (e.g. equilibrium between water vapor humidity and moisture content in the fiber, heat released by the fiber when absorbing humidity) have been manually implemented in the models.

Thus, moisture absorption equations can be simplified as follows [2, 3]:

$$\frac{dM_s}{dt} = \frac{8D_f}{d^2} (M_e - M_s)$$

$$k = \frac{8D_f}{d^2}$$

$$M_s = M_e - (M_e - M_s^0)e^{-kt}$$

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 3). The fiber temperature rapidly reaches values higher than the steam one, due to the heat of moisture sorption, whereas the moisture content ($\text{kg}_{\text{H}_2\text{O}}/\text{kg}_{\text{fiber}}$) increases very slowly, demonstrating that the diffusion coefficient of water molecules into the fiber is the limiting factor of the whole process (Figure 4).

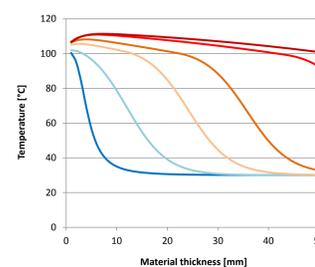


Figure 3. Evolution of the temperature through the thickness of the textile material during the initial transition phase of the process.

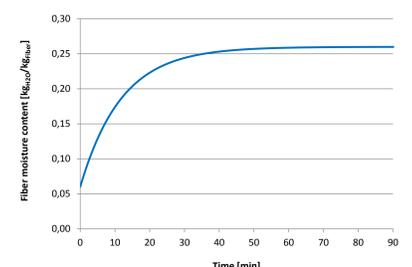


Figure 4. Evolution of the moisture content in the wool fiber for a pre-conditioned (7% initial moisture content) textile material.

Conclusions

The results of the present study have been evaluated thanks to a set of experimental data carried out in a bench scale equipment.

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.

Further developments could lead to the analysis of higher steam temperature treatments, in order to evaluate possible enhancements in the process kinetics and a reduction of the operative process time.

References

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- [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).