INFLUENCE OF FURNITURE COVERING TEXTILES ON MOISTURE TRANSPORT IN A CAR SEAT UPHOLSTERY PACKAGE

Marek Snycerski, Izabela Frontczak-Wasiak

Faculty of Engineering and Marketing of Textiles
Technical University of Łódź
ul. Żeromskiego116, 90-543 Łódź, Poland

E-mail: marek121@p.lodz.pl

Abstract

The conditions of heat and moisture transport in a car-seat upholstery package are briefly presented, and the necessity of investigation especially of moisture transport is stressed. Three upholstery packages of different furniture covering textiles have been tested with the use of a measuring system for assessing moisture transport through flat textiles. The factor of absolute humidity changes over time determined on the boundary between the user and the upholstery package is described, and its usability for estimating a package application presented. An analysis of the curves of absolute humidity changes versus time allows us to draw the conclusion that inserting a component which blocks the moisture transport inside a package can disqualify the whole package, irrespective of the quality of the remaining components. Without forced ventilation inside the package, a package with the thinnest furniture covering textile has the best properties.

Key words:

Upholstery package, car seat, use comfort, moisture transport

Introduction

Factors which influence the comfort in use of upholstery products include not only the mechanical properties of used fabrics [1] but also the hygienic features of the products themselves. Comfort in use may be difficult to define explicitly, but is without doubt readily perceptible. The user's feelings can be divided into physical and physiological. The former have been the subject of our previous investigation; they include the feeling of sitting security (the 'soft hardness' of the seat) and the comfort resulting from proper body arrangement, both of which are linked with a lack of fatigue. The physiological comfort factor can be defined as hygienic comfort, and is conditioned by the microclimate of those fabric layers which are set directly next to the user's skin. It should be stressed that hygienic comfort is equally as important as physical comfort, because in the case of a car driver it influences the ability to maintain concentration and the time when a driver begins feeling tired, and both these features considerably influence the safety of travel.

An important problem, the subject of many researchers' investigation, is the methodology of hygienic comfort estimation, both of the whole upholstery package and of its particular component parts. The use of an apparatus for investigating water moisture transport through flat textiles (clothing fabrics) [2] to estimate the dynamic of moisture changes on the boundary between artificial skin and a upholstery package is also the subject of the present work. It is well known that, an upholstery package is in general manufactured as a multi-layer complex construction of flat textiles and of materials which ensure appropriate elasticity. The thickness of the particular components is from a few to several dozen times higher than the thickness of classical textile clothing fabrics, and this is the reason that such investigations as ours should be carried out. Nowadays complex measuring systems are used for investigating the physiological comfort of upholstery packages, e.g. dummies equipped with sensor systems, special climatic chambers, wind tunnels etc. [3]. The authors' aim was to check the possibility of estimating one of the physiological climate components, and the upholstery package's ability to transfer moisture from the zone near the skin was chosen.

Every human being is the source of heat energy within a range of 150W to 300W power, depending on their emotional state and the kind of action being carried out. The temperature of a human body is maintained at a level of about 37°C; as the temperature of the environment is usually below that value, all the amount of the heat created must be conveyed out to the environment. An up-to-date solution for thermal comfort control of a car seat is to use microcapsules containing phase change material (PCM) [4]. PCM is a substance which absorbs and cumulates important amounts of heat energy over the time of transfer from the solid to the liquid state; this energy is later emitted over the time of the inverse conversion. For example, a one-millimetre thick layer of PCM microcapsules deposited on the bottom side of an upholstery fabric can absorb about 100 kJ/m^2.

The transport of heat through an upholstery package is additionally disturbed by the main human temperature control system, that is, perspiration. This results in the requirement that an upholstery package should be characterised by its ability to transport moisture, independently of whether it maintains appropriate thermal properties. This ability is based on absorbing moisture by the package, and afterwards by carrying it out to the environment. Thereby the physiological package properties are formed by two factors: the moisture accumulation ability and the ability of water vapour transport. The latter is determined by the intrinsic structural ventilation conditions in the package. The driver and passenger undergo multidirectional vibrations caused by the car's motion. Then the package is exposed to alternating stresses of compression and relaxation, which in the case of applying elastic and porous layers in the package is conducive for carrying out water vapour on the basis of a pump effect. However, the development of road engineering and car construction means that this effect is of less and less importance. This has induced constructors to apply systems of forced ventilation to upholstery packages in modern car seats. Such systems include mini-suction fans installed in the bottom and back of the car seat. The directions of heat and moisture fluxes from the passenger body to the environment through the car seat are presented in Figure 1.

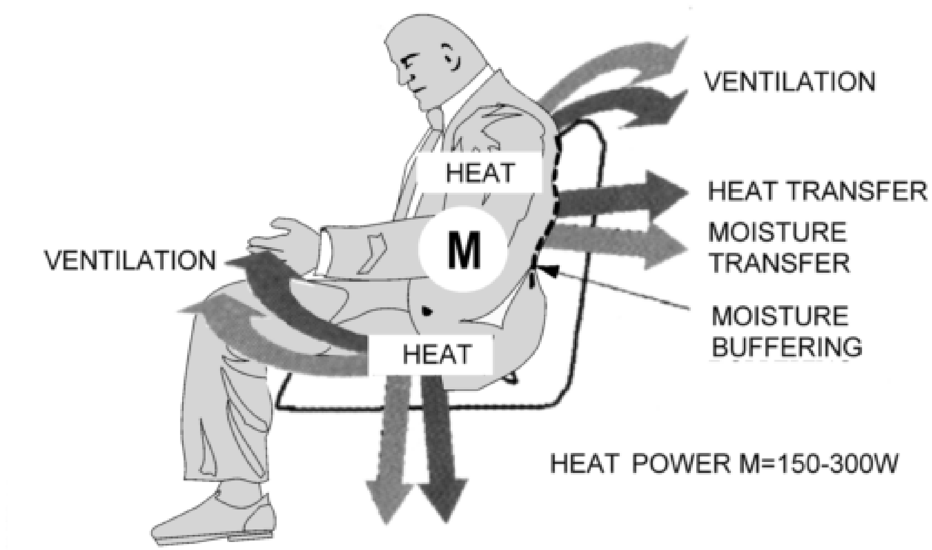

Figure 1. *Heat and moisture streams in an upholstery car seat*

Moisture transport in an upholstery package is a very complex phenomenon. To simplify the problem, it can be assumed that the processes listed below take place at the same time:

- Diffusion of water vapour through air canals (the pores) in textiles and other package composition components, e.g. in polyurethane foam (on condition that the canals are not closed);
- Absorption of moisture and its transport inside the fibres (on condition that the fibres used are hydrophilic);
- Desorption of moisture from the fibres;
- Capillary transport of condensed water through the structural capillaries of textiles used;
- Adsorption of water on the fibre's surface, the migration of this water along the surface, and penetration into the dry parts of the package.

To these factors, moisture absorption by fibres can be classed as least essential of all, considering that in general, synthetic fibres of very small moisture absorption are used. However, in recent times the substitution of rigid polyurethane foam (as material for seat construction elements) by moulders of coconut nonwovens can be observed. This results in a relatively high content of natural fibres in the package composition.

The motion of air and heat inside the package influences the processes mentioned above. Air motion is conductive for water vapour transport through the net of the package's structural pores, whereas the heat accumulated inside the package is conductive for water vaporisation from the fibres. This means that for the package to behave appropriately, it is of essential importance that the individual package components must be conductive for the simultaneous occurrence of all processes which generate moisture transport. A package should therefore be composed of at least the following elements:

- furniture covering textile (upholstery textile) which must be hydrophobic independently of its aesthetic features; this layer should secure the feeling of dryness;
- hydrophilic material which should accumulate moisture; this layer must however be sufficiently thin to allow immediate, maximum moisture vaporisation to further seat layers;
- material of the 'pump type'; this can be a polyurethane foam layer, distance knitting, and coconut nonwoven; the aim of this layer is to carry out air together with moisture mechanically.

Object of investigation

Three upholstery packages of following structure have been used for the tests performed:

a) layer I: polyester velour knitting laminated with polyurethane foam, total layer thickness of 4.6 mm, layer II: needled nonwoven of secondary fibres with the use of wool, layer thickness of 4.7 mm; layer III: polyurethane foam 47 mm thick and latex-coconut mat 25 mm thick. The total thickness of the package was 81.3 mm,
b) layer I: polyester velour knitting 1.8 mm thick; layers II and III as in package a). The total thickness of the package was 78.5 mm,
c) layer I: polyester distance knitting, velourised on one side, 3.7 mm thickness; layers II and III as in package a). The total thickness of the package was 77.5 mm.

Investigation methods

The measuring system (Figure 2) constructed in the Department of Clothing of the Faculty of Engineering and Marketing of Textiles at the Technical University of Łódź, Poland consists of a cylindrical chamber proper and an external insulation chamber, the task of which is to limit heat exchange between the chamber proper and the environment.

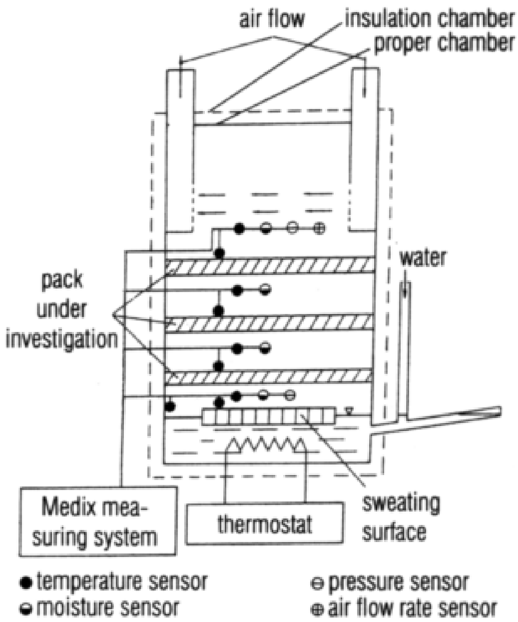

Figure 2. A schema of the apparatus for the assessment of moisture transport through flat textiles

In the lower part of the chamber proper, there is a ‘sweating’ surface (simulating human skin) which is moistened with water by means of a capillary system. The magnitude of ‘sweating’ can be altered by putting special diaphragms over the 'skin’, which allows the rate of moisture evaporation to be changed within a range from 0.09 to 1.9 ml/m^{2}min. Directly under the ‘artificial skin’ there is a source of heat maintaining a constant temperature of the sweating surface with an accuracy of 0.5°C. A material, or a pack of materials under investigation, is placed over the surface of the ‘skin’. Temperature and moisture sensors are placed on both sides of every package layer. The space over the material under investigation is ventilated with the possibility of measuring the air velocity.

Tests

The packages were placed in the apparatus for investigation of heat and moisture transport through flat textiles and clothing packages which has been described above [2]. The tests were conducted under the following conditions:

- environment temperature at a level of 28.4+1.5°C,
- temperature of the artificial skin at a level of 26.5+1.5°C,
- related humidity (moisture) of the environment 19+3%.

The absolute moisture content on the package surface (the surface from the artificial 'skin’ side, in front of the package) and on the left package side (the coconut nonwoven side after the package) were recorded in one-minute time intervals. Example runs of humidity changes for a c-type package are presented in Figure 3.

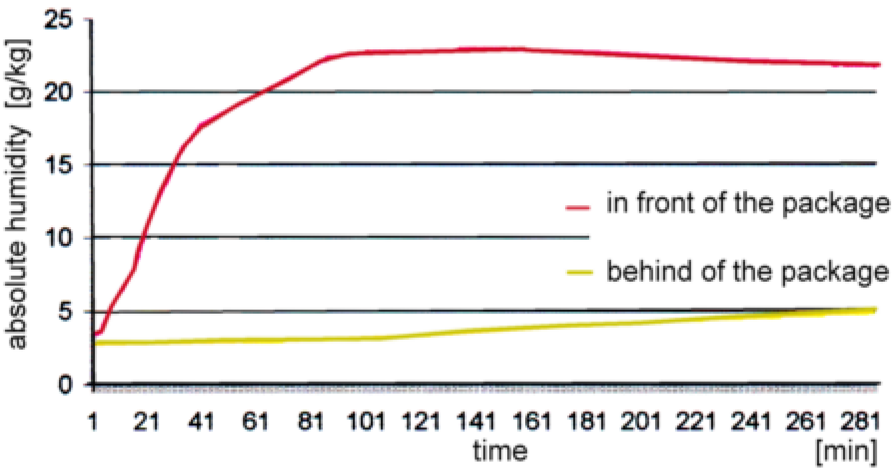

Figure 3. Absolute humidity changes as a function of time for package ‘c’

As can be seen from Figure 3, over the 280 minutes of the investigation time , the humidity after the package has changed only slightly (from 2.5 g/kg to 5 g/kg) despite the humidity increase in front of the package from 2.5 g/kg to 23 g/kg over the time of 90 minutes. This means that the moisture generated has been almost totally accumulated in the package. It can be assumed that the package under investigation has ‘too good’ thermo-insulation properties, which results in inside space remaining ‘cool’, preventing evaporation of the package moisture; it is also possible that one of the package components blocks the moisture flow. The lack of forced ventilation from the inside of the package in our investigation (the lack of the ‘pump effect’ mentioned before) was also a factor which facilitated moisture build-up in the package. On the other hand, the slope of the humidity curve in front of the package can be a 'package factor’ (designated here by W_k) which characterises the dynamic of water vapour penetration through the package:

$$W_k = \Delta W / \Delta t, \quad \text{in g min/kg}$$

where: ΔW – change of moisture amount in front of the package,
t – the time over which this change was observed.

A small slope of the curve (small value of the factor W_k) means that the package has great ability to moisture absorption over a long time, or has great ability to transport moisture. If the ability to store or transmit moisture is small (e.g. zero in extreme conditions), the humidity curve in front of the package has a steep run and the humidity in this place achieves a state of saturation in a relatively short time. At the same time, any humidity changes behind the package would be observed. The very small slope of the humidity change curve behind the package represents the storage supremacy of moisture beyond the water vapour transport. In the case of a good package's transport properties, the humidity curve behind the package should rise fast, and after a certain time the humidity levels in front of and behind the package should be similar.

Because the humidity curves behind the package have a near-similar shape for all the three packages investigated, it was accepted that the properties of the individual packages will be characterised by humidity change curves in front of the package, which are related to the following package factor values:

for package a) - W_{ka} = 0.75,
for package b) - W_{kb} = 0.65, and
for package c) - W_{kc} = 0.27.

As can be seen, package 'c', containing a velourised distance knitting as the furniture covering material, has the best properties . As the remaining package components are the same in all of the analysed packages (apart from the outside layers), the package properties are determined by the outside layer, the furniture-covering textile. All of the packages we analysed have an incorrect structure. Minimum humidity changes behind the package were recorded in every case, which indicates that moisture transport blocking barriers exist inside the package. An analysis of the structure of the individual package components allowed us to assume that the polyurethane foam layer which has closed internal spaces is responsible for moisture transport blocking. To confirm this hypothesis, experiments with the use of only the outside package layers (the furniture covering textiles and the nonwoven) were carried out.

An example run of the humidity changes on the outside boundaries of a package containing a velourised distance knitting and an underlay nonwoven are presented in Figure 4.

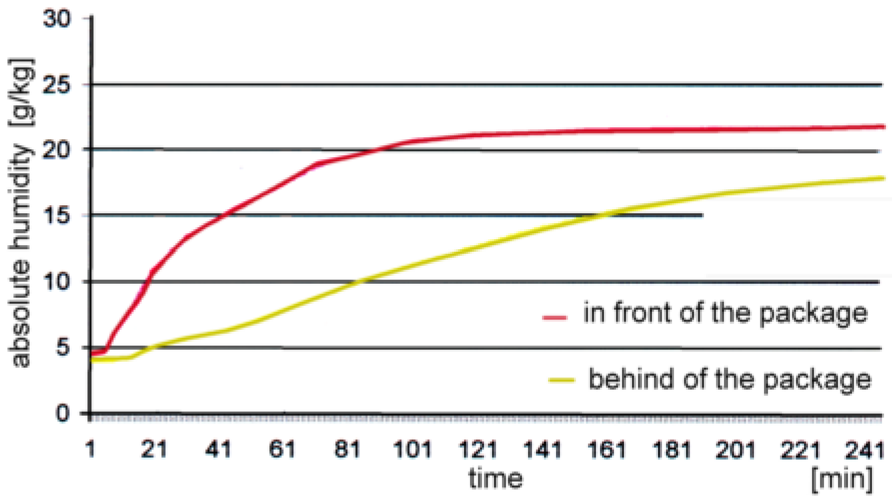

Figure 4. Absolute humidity changes as a function of time for the outside layers of package 'c'

In comparison to the curves for the whole package presented in Figure 3, an essential effect of moisture transport (moisture penetration to the other package side) can be seen here. The humidity behind the package changed from 2.5g/kg to 17 g/kg over 240 minutes, while the humidity in front of the package (beginning after about 100 minutes) was approximately equal to the level of 22 g/kg recorded for the whole package. The factor W_{kcout} for the outside layers of package 'c' equals 0.16 g/kg and, in accordance with our expectations, is smaller than the factor for the whole package. For the remaining outside layers the factors are equal: W_{aout} = 0.55 g/kg and W_{bout} = 0.18 g/kg.

Similarly to the whole package, the outside layer of package 'a' also has the smallest ability to transport moisture. This results from the application of a thin polyurethane foam layer, which was laminated with upholstery knitting. The foam layer characterised by open and closed pores is only partially a transfer barrier for moisture.

Summary

1. The factor of absolute humidity changes over time determined on the user-upholstery package boundary can be useful for estimating the application of such packages.
2. Insertion of a component blocking the transport of moisture (e.g. polyurethane foam of a thickness greater than 5 mm) inside a package disqualifies the whole package, irrespective of the quality of the remaining components.
3. Under conditions of no forced ventilation inside the package, the package with the thinnest furniture covering textile has the best properties ; in our investigation this was the polyester velourised knitting.
4. Worse results which were obtained for the package with a one-side velourised knitting distance, as the outside layer does not disqualify products of such a type of furniture covering textiles. The advantages of this material will be demonstrated in an investigation simulating real alternated loading of the package.

Acknowledgement

The authors would like to thank Dr J. Zieliński from the Department of Clothing at the Technical University of Łódź for making the apparatus for assessment of moisture transport through textiles available to us, and for his valuable help in conducting the measurements.

References

1. *I. Frontczak-Wasiak, M. Snycerski, 'Use Comfort Forming of a Upholstery Package', (in Polish), Architektura Tekstyliów, No. 1 – 2, 2000.*
2. *J. Zieliński, P. Majewski, 'A Measuring System for the Assessment of Moisture Transport Through Textiles', Fibres & Textiles in Eastern Europe, Vol. 5, No.3 (18) 1997, pp. 57-59.*
3. *'Development of Standard Test Methods for Evaluation of Thermal Climate in Vehicles'; Final Report of EU-Project SMT4-CT95-2017.*
4. *B. Pause, 'Driving More Comfortable with Phase Change Material', Technical Textiles International, March 2002.*