THERMAL INSULATION AND THERMAL CONTACT PROPERTIES OF UPHOLSTERED LEATHER FURNITURE IN WET STATE

Lubos Hes[1], **Aura Mihai**[2], **Mariana Ursache**[2]

[1]Technical University of Liberec, Czech Republic
[2]Technical University of Iasi, Faculty of Textiles, Leather and Industrial Management, Romania

e-pošta: lubos.hes@gmail.com

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Abstract

Contemporary furniture ought to provide high level of sensorial and thermal comfort to its users, both in dry state and after partial wetting due to increased air humidity and sweating of the seated person. This paper aims to experimentally determine thermal resistance, thermal conductivity and thermal contact feeling (thermal absorptivity) of 10 cowhide and 5 artificial leather samples used for upholstered furniture. The measurements involve samples in both dry and wet state. It was found that the increased relative moisture of the samples caused their thermal resistance to decrease rapidly, intensifying the feeling of coolness.

Keywords: thermal comfort, leather, upholstery furniture

INTRODUCTION

Upholstered furniture is a common part of rooms, offices, bedrooms and public spaces. Seated people feel comfortable when the heat and moisture transfer from their body and the furniture maintains thermal equilibrium of their bodies without causing sweating or shivering. Therefore, the level of thermal and evaporation resistance of the furniture is very important. Part of these resistance levels depends on thermophysiological parameters of the fabrics creating the furniture surface. Surface of this furniture can be created using textile fabrics or natural and artificial leather [1].
Important part of total comfort of the furniture is the sensorial comfort, which involves selected mechanical and thermal parameters of the used surface fabrics, namely:

- Friction + profile
- Moisture behavior characteristics influencing the fabric / skin friction
- Thickness + compressibility
- Bending + shearing stiffness (at low and large deformations)
- Elasticity, tenacity
- Warm-cool feeling (transient heat transfer)

Besides thermal resistance and thermal conductivity of furniture fabrics, this study also examines the thermal-contact feeling properties of these fabrics.

Humidity is another important aspect of thermal comfort [2]. A seated person will usually feel uncomfortable when humidity builds up at the skin surface because moist skin creates increased friction coefficients, causing it to stick to clothing or chair upholstery and inhibiting the small movements required to shift weight off pressure points. Unfortunately, current scientific literature does not provide papers on the effect of moisture on selected thermal and sensorial properties of upholstery fabrics.
Therefore, the main objective of this paper is the experimental analysis of the effect of moisture on thermal resistance, thermal conductivity and thermal contact feeling (thermal absorptivity) of 10 cowhide and 5 artificial leather samples used for the upholstered furniture. These properties were measured at several levels of relative moisture U % related to ultra-dry mass. The used measuring instrument was the ALAMBETA, which enables non-destructive and fast testing of fabric samples in both dry and wet state. Obtained results were statistically processed and comfort properties of the studied samples were plotted as the function of their moisture. The samples which offered the highest thermal resistance and the driest thermal contact feeling were recommended for the production of the upholstered furniture with optimal thermal comfort [3].

EXPERIMENTAL

Used instrument and tested properties

The ALAMBETA instrument was used in this study to measure thermal conductivity, thermal absorptivity, thermal resistance and sample thickness. In mathematical processing, this principle depends on time course of heat flow passing through the tested fabric due to different temperatures of bottom measuring plate and measuring head. When the measuring head touches the fabric, it starts the measurement lasting only several minutes. This indicates that reliable measurements on wet fabrics are possible, during which the sample moisture remains almost constant [3].

Thermal conductivity coefficient λ of polymers is quite low, from 0,2 to 0,4 W/m.K, and that of textiles ranges from 0,033 to 0,01 W/m.K. Thermal conductivity of steady air by 20°C is 0,026 W/m.K, while thermal conductivity of water is 0,6 W/m.K, which is 25 times higher. This is the reason why the presence of water is undesirable in textile materials [4].
Thermal resistance R depends on fabric thickness h and thermal conductivity λ:

$$R = h/\lambda \ [m^2K/W] \qquad (1)$$

Thermal absorptivity b of fabrics was introduced by Hes [5] to characterize thermal feeling during short contact of human skin with the fabric surface. The measured fabric was simplified into semi-infinite block with thermal capacity ρc [J/m³] and initial temperature t_2. Unsteady temperature field between the human skin (with temperature t_1) and fabric with respect to boundary conditions offers a relationship, which enables a determination of the heat flow q [W/m²] course passing through the fabric:

$$q = b\,(t_1 - t_2)/(\pi\tau)^{1/2}, \quad b = (\lambda\rho c)^{1/2} \ [Ws^{1/2}/m^2/K] \qquad (2)$$

Whereby ρc [J/m³] is thermal capacity of the fabric and the term b presents its thermal absorptivity. Higher levels of thermal absorptivity of the fabric result in cooler feeling. In textile praxis, this parameter ranges from 20 $Ws^{1/2}/m^2K$ for fine webs to 600 $Ws^{1/2}/m^2K$ for heavy wet fabrics..

Tested samples

Results of measurements at contact pressure 200Pa and their evaluation

Figure 1: The new ALAMBETA tester

Figure 2: The upholsted furniture

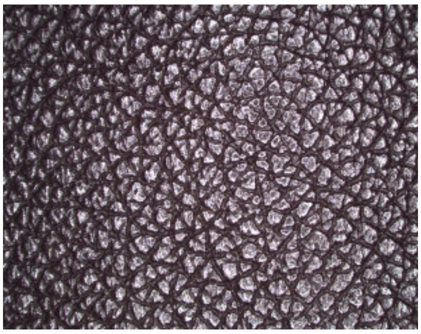


Figure 3: The cowhide surface

Sample	Composition	Substrate	Thickness [mm]	Thermal absorbitivity $Ws^{1/2}/(m^2K)$ i U = 10 %
1	Cowhide		0,54	356
2	Cowhide		0,77	270
3	Cowhide		0,86	275
4	Cowhide		0,89	276
5	Cowhide		1,01	291
6	Cowhide		1,12	277
7	Cowhide		1,19	306
8	Cowhide		1,47	297
9	Cowhide		1,55	284
10	Cowhide		1,63	281
11	PU coating 60%	PES knit 40%	0,67	315
12	PU coating 60%	PES knit 40%	0,79	297
13	PU coating 70%	PES knit 40%	1,05	420
14	PU coating 70%	PES knit 40%	1,13	390
15	PU coating 70%	PES knit 40%	1,18	374

Tab. 1 Composition and properties of the tested samples (the cowhide and the laminated knitted fabric)

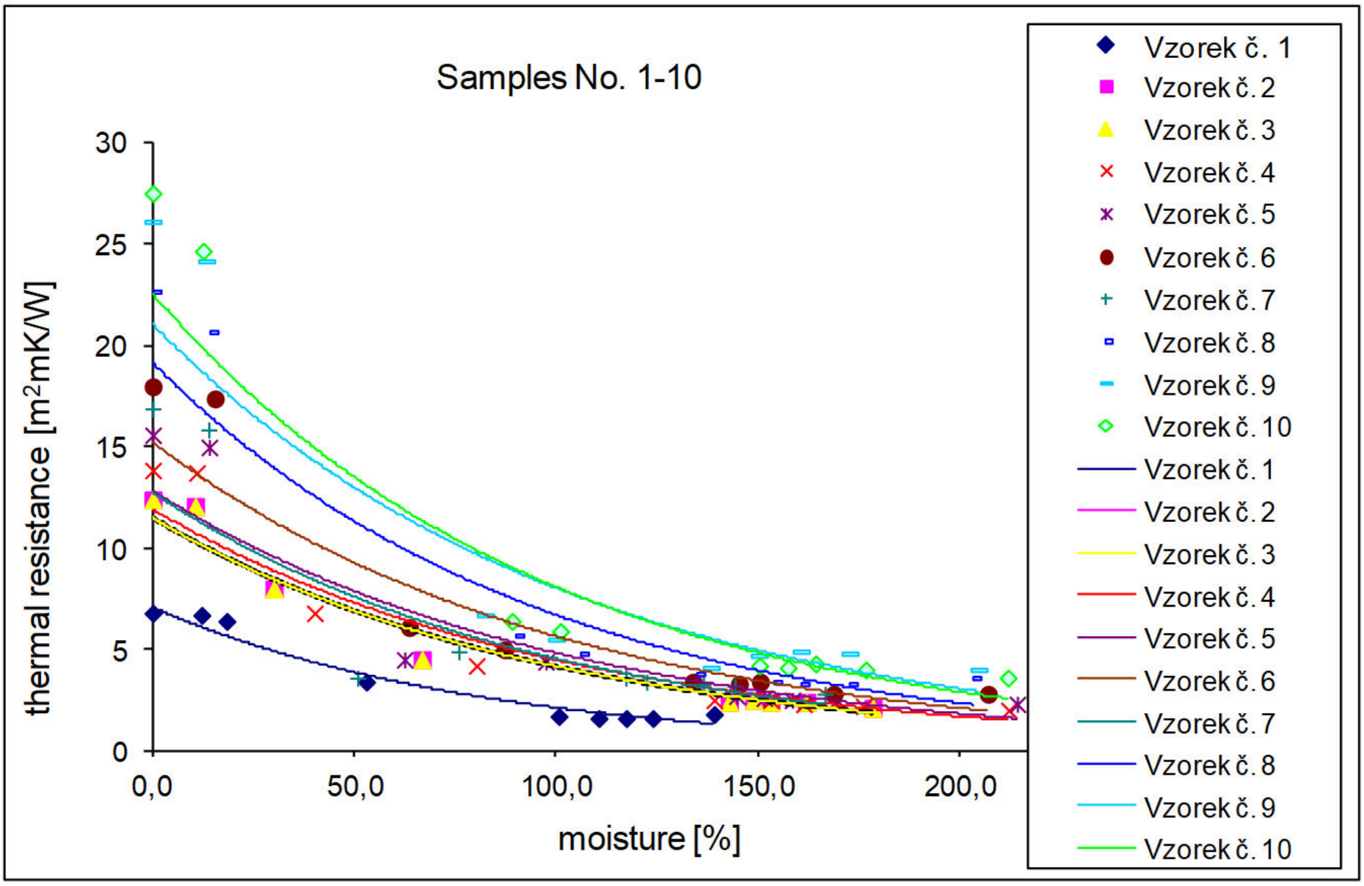


Figure 4: Thermal resistance levels determined on wetted samples made of natural cowhide leather. Thermal resistance levels determined on wetted samples made of natural cowhide leather. The decrease of thermal resistance levels with the increased moisture seems considerable. This is solely due to large moisture extension, since natural leather is very hydrophilic. At medium moisture levels, thermal resistance of natural leather surface of the furniture remains high. This feature makes natural leather very comfortable. The Czech word “Vzorek“ means “sample“.

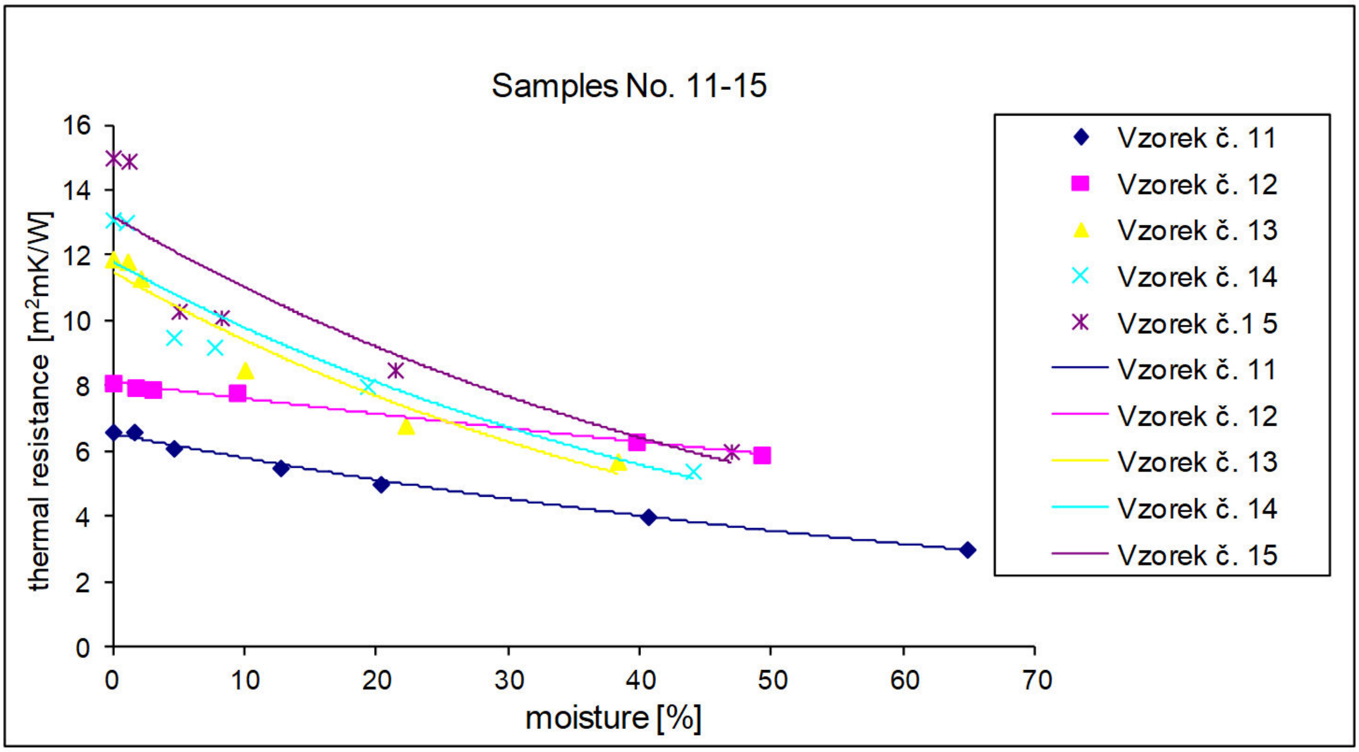


Figure 5: Thermal resistance levels determined on wetted samples made of artificial leather. The decrease of thermal resistance levels with increased moisture seems relatively slow. This is caused by low moisture extension, since artificial leather is almost hydrophobic. The Czech word “Vzorek“ means “sample“.

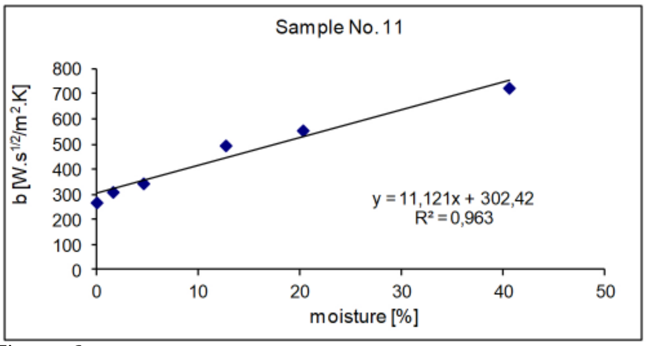
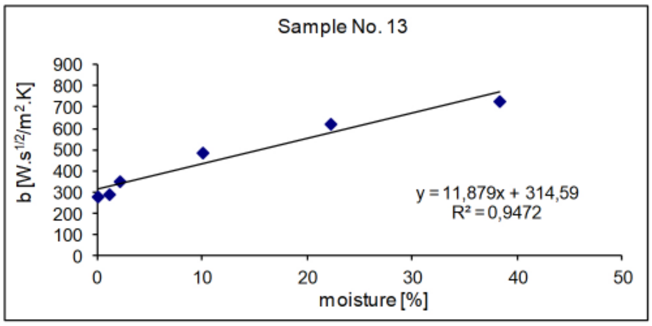


Figure 6.



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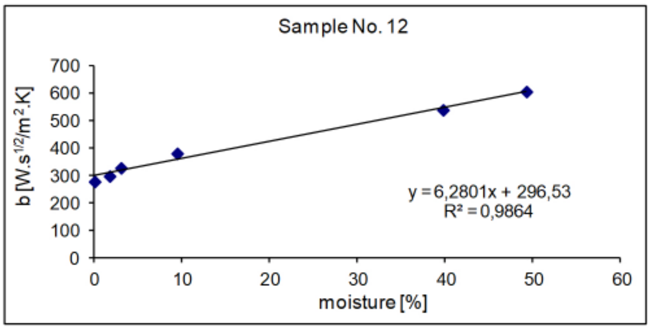

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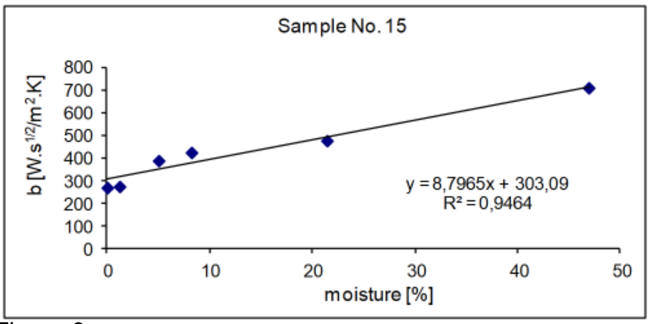


Figure 9.

Figures 6 - 9: Thermal absorptivity levels determined on wetted samples of artificial leather.

The cool feeling increases with increased moisture rapidly, despite small moisture extension; this is due to the fact that artificial leather is not very hydrophilic and the moisture remains in surface layers of upholstery fabrics. The cold feeling felt at higher moisture levels makes artificial leather quite uncomfortable.

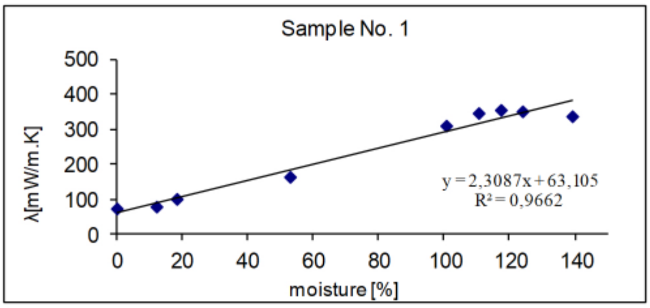
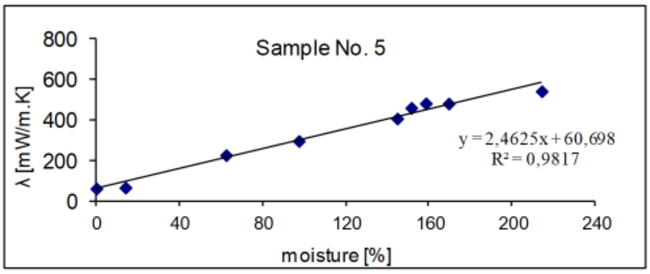


Figure 10.



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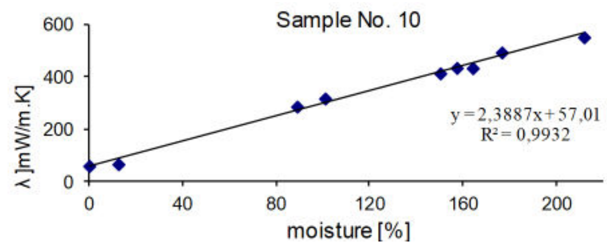

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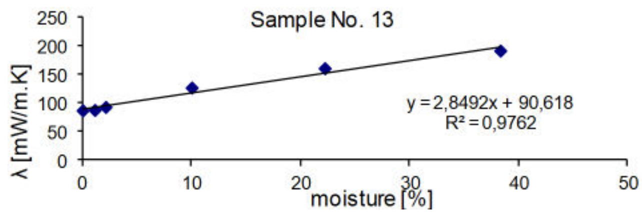

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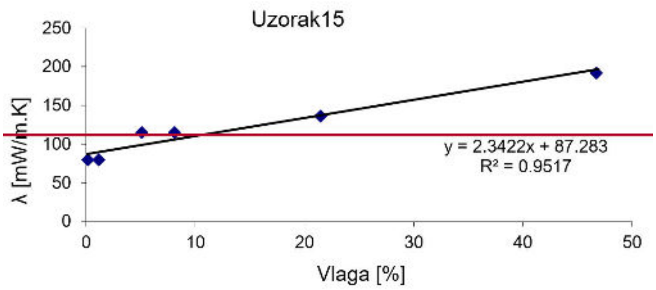

Figure 14.

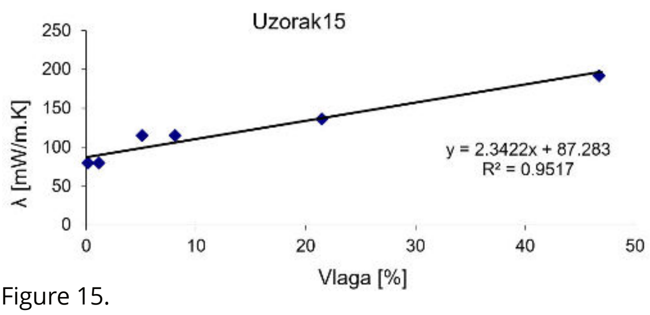

Figure 15.

Figures 10 - 15: Thermal conductivity λ determined on wetted samples of natural (sample 1-10) and artificial leather. Initial (dry) and medium levels of thermal conductivity of natural leather are lower. The increase of thermal conductivity in artificial leather with increased moisture is quick despite small moisture extension, since artificial leather is quite hydrophobic. The initial low thermal resistance levels (as follows from the Eq. (1) can make furniture upholstered with artificial leather uncomfortable to certain extent.

CONCLUSIONS

IThe aim of this study was to determine thermal resistance, thermal conductivity and thermal contact feeling (thermal absorptivity) of 10 cowhide and 5 artificial leather samples used for the upholstered furniture, both in dry and wet state. The measurement was conducted with the fast testing ALAMBETA instrument. It was found that the increased relative moisture of the samples caused their thermal resistance to decrease rapidly, thus increasing the feeling of coolness.

Samples made of natural leather all exhibited lower thermal conductivity and their thermal absorptivity was always higher compared to artificial leather. The moisture absorbed at the levels typical for the practical use of the furniture resulted in slower decrease of thermal resistance of natural leather samples and slower increase of the cool feeling, when compared to artificial leather. Sample No. 2 exhibited the warmest thermal contact feeling.

Full analysis of comfort properties of upholstering fabrics would require additional determination of their water vapor permeability.

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Corresponding author:

Lubos Hes, Prof. PhD, DSc, Dhc
Technical University of Liberec, Faculty of Textiles
Studentska 2
461 17 LIBEREC
Czech Republic
lubos.hes@gmail.com