Thermal conductivity and moisture permeability in mattress

PROVODNOST TOPLINE I PROPUSNOST VLAGE U LEŽAJU

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Abstract

The aim of the work was to study the relationship between the structure of a mattress and its moisture and thermal conductivity. Moisture and thermal conductivity were recorded during examinees' sleep by means of measuring sensors placed at different positions relative to the human body. The data obtained by measuring moisture and temperature during sleep of three examinees, an adult male, an adult female, and a child, were analysed. The results of the data analysis enable appropriate selection of materials and structure for a mattress, upgrading its quality.

Key words: thermal conductivity, moisture permeability, mattress structure, mattress quality.

Sažetak

Cilj rada je istraživanje odnosa između konstrukcije madraca i propusnosti vlage i topline. Propusnost vlage i topline mjerena je na sljedećim uzorcima:

1. madrac s dvostrukom opružnom jezgrom
2. madrac s dvostrukom opružnom jezgrom sa štep dekom od pamuka i vune.

Ispitanici u pokusima su muškarac, žena i dijete. Propusnost vlage i topline bilježena je pomoću elektroda postavljenih na različita mjesta u odnosu na tijelo ispitanika tijekom njegova spavanja na ležaju. Zabilježeni podaci prikazani su grafički i statistički su analizirani. Za testiranje postojanja značajnih razlika u medijanima temeperature i vlage kod uspoređivanih uzoraka uporabljen je neparametarski Mann-Whitney's test. Značajne razlike u provodnosti vlage između uzoraka 1 i 2 pokazle su se kod testiranja vlage izmjerene u točkama najbližim tijelu ispitanika (pokrivač i gornji sloj madraca). Viši postoci vlage kod uzorka 1 na tim mjestima dokazuju manju provodnost konstrukcije ležaja uzorka 1. Manji broj statistički značajnijih razlika dobiven je kod testiranja serija temperature no i tu rezultati idu u prilog kvalitete konstrukcije uzorka sa štep dekom. Interpretacija grafičkih prikaza rezultata mjerenja pokazuje da je provodnost vlage i izolacija temperature bolja kod uzorka 2 (sa štep dekom).

Ključne riječi: vodljivost vlage i topline, konstrukcija madraca, kvaliteta ležaja.

1. INTRODUCTION

Humans spend a third of their life sleeping. It is well known that sound sleep is a prerequisite for an agreeable disposition, for good working capacity and existence in general. Researches into conditions affecting sleep are given more and more significance.

From the physiological and psychological point of view, sleep is influenced by two groups of factors. The first marks the biorhythm, the phenomenon in the human organism which by means of its "inner clock" determines the time for sleep. The second group of factors comprises sleeping conditions. There are several of them, and they affect sleep even more than those in the first group. The second group comprises: illumination, noise, temperature, moisture, bed structure, cover, pillow, etc.

The human body continuously produces thermal energy. The feeling of coldness and warmth depends upon speed by which thermal energy is transferred from the surface of the body into the environment. Too quick an exchange of temperature induces the feeling of coldness, and too slow an exchange the feeling of unpleasant warmth. Besides temperature, the human body continuously exudes liquid (moisture) through the skin. The disposition and quality of sleep also depend upon the materials the body is in contact with, their capacity to absorb liquid and temperature.

Science has been involved in the studies of sleep [1], [3], [4] with emphasis on:

- exudation of liquid and temperature exchange as physiological phenomena;
- conditions in the sleeping environment;
- temperature conductivity of materials currently in use in upholstered furniture;
- moisture conductivity of materials currently in use in upholstered furniture.

Scientific methods are, therefore, to be applied to determine the quantity and type of materials needed for comfortable and healthy sleep in different conditions, uniting requirements set on upholstered furniture into a harmonious and healthy entity.

2. TEMPERATURE AND MOISTURE CONDUCTIVITY

Diffusion of temperature and the transfer of liquid (moisture) are influenced by materials which we sleep on and cover ourselves with, as well as by the surrounding climate. Temperature and moisture conductivity through materials the mattress is made of is, together with mechanical characteristics, the main parameter of the comfortableness and quality of a mattress.

Temperature Conductivity

A healthy human body maintains a temperature between 36 and 37 °C. The production and transfer of temperature is to be balanced. While any of the mechanisms precludes thermal regulation, the body temperature either rises or drops. Both these extremes are unhealthy and uncomfortable for human life, therefore a bed should be provided with materials which surface and covering do not preclude, but enhance, thermal regulation.

Moisture Conductivity

Transpiration, which under extreme circumstances reaches 5 to 10 l daily, ensures thermal regulation [6]. A good mattress and linen should not induce heat transpiration. Despite this, transpiration occurs when the temperature of the environment increases (during the heating season or summer months). Besides heat transpiration, there are other types of direct transpiration, caused by other circumstances, e.g. disease or psychological states. The body moisture created during sleep should be conveyed from the surface layer into the inner parts of the mattress's upholstery and into the cover (0.5-0.75 l/night), [6]. During the following day this moisture should evaporate into the environment.

3. PAST RESEARCHES INTO THERMAL AND MOISTURE CONDUCTIVITY

The temperature and moisture conductivity are studied on a number of standard structures of mattresses [3]. A SINA apparatus with six measuring sensors (∅=2mm, l=5mm) was applied. The measuring points were predetermined. It was found that the locations of highest temperatures and moisture are in the area of the chest, and that from there both parameters gradually decrease. Brezigar arrived to similar findings [1]. According to [3] with regard to the temperature and moisture conductivity in the mattress structure, the highest moisture level is in the upper layer of the mattress (20 - 30 mm), therefore this is the most significant part for the human health. Some recent references concerning this topic are given in [6] and [2].

Methods for measuring thermal and moisture conductivity through the mattress by means of special inserts have been developed. Results of these researches and investigations yield objective criteria for evaluation of the quality of the mattress.

4. AIM AND METHODS OF RESEARCH

The aim of these researches was to establish relationships between thermal and moisture conductivity and the mattress structure.

Thermal and moisture conductivity from the body of the examinees and through layers of the mattress were measured using new equipment, developed in the Department for the Final Processing of Wood at the Faculty of Forestry, University of Zagreb, in co-operation with experts from ISKRA Instruments Otoče, Slovenia. The apparatus has 12 measuring sensors, six for temperature and six for moisture. The measuring points within layers of the mattress were selected in advance. The location of measuring sensors is shown on Fig. 1.

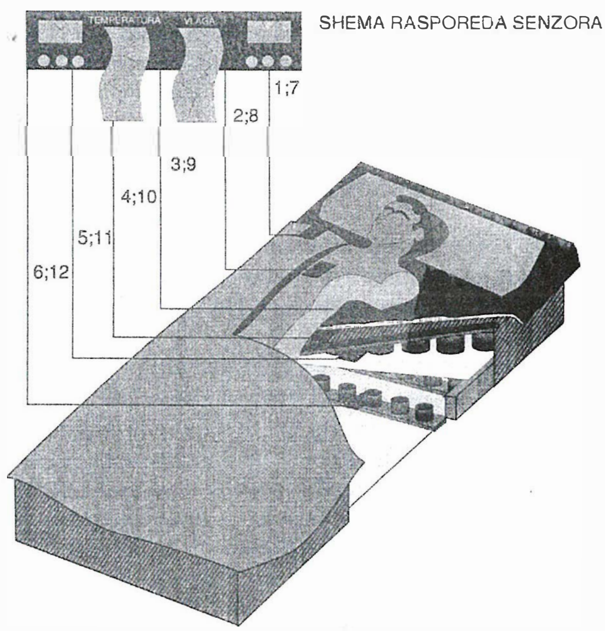

Fig. 1. Location of measuring sensors: 1-6 for temperature, 7-12 for moisture.
Sl. 1. Raspored mjernih mjesta: elektrode 1-6 bilježe temperaturu, 7-12 vlagu.

The measuring sensors operated under electrical impulses every 60 seconds (every 5 seconds one measuring sensor). A device with a YOKOGAWA 12-channel printer recorded the signal onto paper strip.

The tested samples were the following:

Sample 1 - mattress with a double spring core (BONELL) of natural materials;

Sample 2 - mattress with a double spring core (BONELL) of natural materials with an added bedspread of cotton.

An effort was made to maintain uniform conditions during all tests. This pertained to the room temperature, which decreased linearly from 19.9°C to 17.9°C, but also to other conditions for sleep. During all tests the same linen and clothes were used: bedspread on mattress (180 g/m^2, 100% cotton), sheet (200 g/m^2, 100% cotton), cover (360 g/m^2, 80% wool, 20% synthetic regenerate), blankets (360 g/m^2, 100% wool) and nightwear, nightdress (80 g/m^2, 100% cotton) and pyjamas (100 g/m^2, 100% cotton).

All tests were carried out on three persons (a 36 year old male, a 36 year old female, and a 10 year old child), all of whom slept for six nights on each type of mattress. Tests were carried out in the period between 30 September and 20 January.

The recorded analogue signals were digitised, and the obtained data input into tables and graphically presented in the form of:

- distributions of relative frequencies of temperature and moisture for all nights (per person, for each sensor, in both samples). Comparative graphs with results of corresponding sensors in two samples enable conclusions about the influence of the presence of the bedspread on the comfort during sleep.

- average values of temperature and moisture by hours of sleep for each sensor. Based on such tables and graphs, conclusions were drawn about the difference in thermal and moisture conductivity of the two samples.

5. TEMPERATURE MEASUREMENT RESULTS

The sensor in the ambient measured the ambient temperature, which proved to be uniform. The temperature decreased linearly through the night, from 19.9°C to 17.9°C.

The sensor in the cover recorded uniform temperature already in the second hour of sleep, and it ranged between 31 i 32°C (during the first hour 28.5 °C).

Sensors under the sheet. In the sample without a bedspread this sensor is on the mattress and in the sample with a bedspread the sensor is on the bedspread. The sensors recorded marked differences in the change of temperature. In Sample 1, during the first hour the average temperature was 28.6 °C, after which the average varied between 30.7 and 32°C. The temperature in Sample 2 averaged 26°C during the first hour, after which the average temperature remained between 29°C. and 31°C. Temperatures of the upper side of the body were recorded to be 2 to 2.5°C higher.

Fig. 2. shows results obtained from temperature measuring sensors under the sheet for all nights for the adult female. Temperatures in Sample 2 show that the warming up of the bedspread takes some time but also that it ensures the warmth is kept. Similar results are obtained for the adult male and the child.

The sensor under the bedspread, on the mattress was active only at the sample with the bedspread. During the first hour the temperature was around 23.2°C, after which the average temperature varied between 26.4 to 27.4°C.

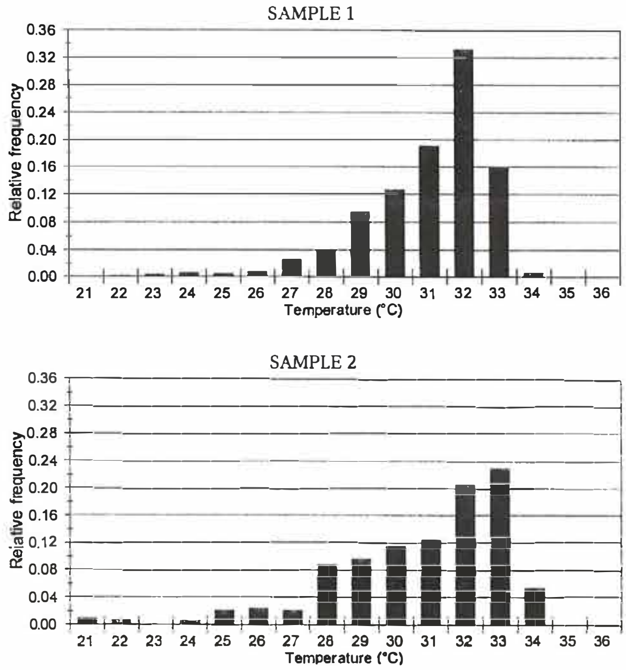

Fig. 2. Temperature distribution for the adult female measured under the sheet on the mattress (Sample 1), i.e. on the bedspread (Sample 2).
Sl. 2. Histogram relativnih frekvencija temperature izmjerene kod ispitanika (žena) ispod prostirke na madracu (uzorak 1), odnosno na štep deki (uzorak 2).

This confirms high temperature conductivity of Sample 2.

The sensor in the mattress, between the lower and the upper spring core. The temperature at this point was significantly lower due to the diffusion of temperature into the ambient.

The sensor under the mattress. The warmth does not reach the bottom layer. On Mattress without bedspread the temperature during the first hour was 17.6°C, after which its average varied between 18.6 and 19.3°C (an increase of 0.7°C). On Sample 1 the temperature during the first hour was in average 16.5°C, and during the rest of the night the average temperature was between 17.5 and 18.5°C (an increase of 1°C).

6. MOISTURE MEASUREMENT RESULTS

The sensor in the ambient measured ambient humidity, which was between 48 and 52%, with maximum variations of 2% throughout the night.

The sensor in the cover and the sensor under the sheet recorded the body moisture. It was determined that:

- during the first hour the moisture was higher, which was most probably caused by calming down and covering the body;
- moisture transpiration already stabilises during the second hour of sleep and such state is maintained throughout the rest of the night;
- moisture on the lower side of the body was higher on Sample 1 for 3% to 5%.

Fig. 3. shows that in Sample 1 (mattress without bedspread) for the adult male high percentages of moisture (60% and higher) are measured more often then in Sample 2. Very similar results are obtained for the adult female and the child, which proves that Sample 2 has better moisture permeability and thus provides healthier and more pleasant sleep.

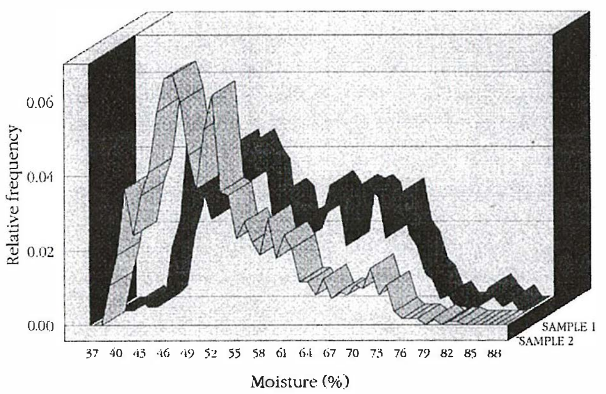

Fig. 3. Distribution of moisture frequency for the adult male (all nights), measured in the cover.
Sl. 3. Razdioba relativnih frekvencija vlage izmjerene u pokrivaču tijekom svih noći kod ispitanika (muškarac).

The sensor under the bedspread. At the beginning of sleep the moisture is highest and it decreases insignificantly during the night.

The sensor in the mattress, between the lower and the upper spring core. A high level of moisture was recorded at this point (from 66% to 70%). The results with the double spring structure of the mattress only confirm previous results obtained in the research of the quality of sleep [3]. The results of measurements of moisture show that during the first two hours moisture in Sample 1 is 2% higher than in Sample 2, and this difference decreased to about 1% later during the night. These data also favour Sample 2.

The sensor placed under the mattress recorded insignificantly higher values during the first two hours of measurement.

Measurement results were statistically processed. Mann-Whitney's nonparametric test was applied to test the hypothesis of equal medians of temperature and moisture in two samples for each individual sensor [8]. Statistically significant differences between Sample 1 and Sample 2 appeared when comparing the sensor in the cover for temperature (child) and for moisture (male and child) (Fig. 3 and 4), as well as sensors for moisture at first lower contact points (woman). It is important to note that the differences in temperature and moisture for a particular structure - mattress, even when statistically insignificant, are in favour of the mattress with bedspread.

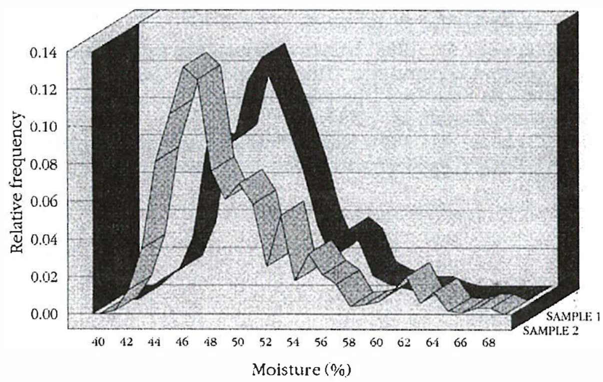

Fig. 4. Distribution of moisture frequency for the child (all nights), measured in the cover.
Sl. 4. Razdioba relativnih frekvencija vlage izmjerene u pokrivaču tijekom svih noći kod ispitanika (dijete).

7. CONCLUSION

1. The temperature and moisture conductivity measuring apparatus, developed in the Department for the Final Processing of Wood at the Faculty of Forestry, University of Zagreb, proved to be suitable for the research of temperature and moisture conductivity in mattresses, as well as for the research of these phenomena in all types of upholstered furniture. The method of measurement can be enhanced by directly connecting the apparatus to a computer system, so as to speed up data processing.

2. The upper layer of the mattress is the most important for comfortableness during sleep, since temperature and moisture gradients are highest in it.

3. Better results were obtained on the mattress with bedspread. The upholstery of Sample 1 proved to be insufficient. Therefore, for high comfortableness during sleep either a modified structure with a bedspread of natural materials or a changed structure is called for.

One of future tasks will be to look for suitable materials regarding the thermal and moisture properties of mattresses.

The most important criterion in the manufacture of mattresses from the physiological and micro climatic aspects is temperature conductivity, and then absorption, permeability and conductivity of vapour. Both properties in question are interdependent. To be able to reach a standpoint regarding their use value, these two characteristics are to be considered jointly, and thus optimised. It is our belief that in future researches a model of an ideal "artificial sleeper" should be developed as a new method which could yield much more objective and, therefore, more valuable results.

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