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EVALUATION OF PHYSIOLOGICAL PROPERTIES OF THE FIRST LAYER GARMENT FOR SPORT APPAREL

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ABSTRACT

Clothing is a protective system which absorbs heat and moisture. Heat and moisture transport depends on ambient temperature and person's physical load. The aim of this paper is to monitor these basic properties by sensors and detectors, which would objectively assess user's physiological comfort. The main focus of this research was to develop a laboratory test method using a simulated exercising load of a human subject and monitoring the temperature and moisture in the limiting layer of clothing under defined climatic conditions. These tests are useful for predicting textile "performance" under prolonged loading condition. The most important material parameters, the thermal resistance R_{ct}, and the resistance to water vapour R_{et} of the tested T-shirts were also evaluated accordance with the EN ISO standard under standard conditions for testing textiles at 20°C and 65% of relative humidity. The overall evaluation of the physiological comfort of the T-shirts is done based on the values obtained from the textile material analysis and the test results from simulated exercising load using probands.

Key Words: *thermophysiological comfort, functional clothing, evaluation of 1st layer clothing*

1. Introduction

Clothing helps thermoregulation when the body itself is not capable of auto-regulation. “Comfort” can therefore be defined as the state of an organism when its physical functions are optimised and its environs, including clothing, do not produce any unpleasant sensations. [1] Heat transport depends on ambient temperature and person's physical load. The aim of this work is to monitor the basic properties by sensors and detectors, which would objectively assess user's physiological comfort. The most important material parameters, the thermal resistance R_{ct}, and the resistance to water vapour R_{et} of the tested T-shirts were also evaluated

in accordance with the EN ISO standard under standard conditions for testing textiles at 20°C and 65% of relative humidity and they are also included in the overall results. [2]

1.1. Evaluation of clothing comfort

In view of the fact that comfort is directly related to physiological state of body, it can be measured quantitatively. An important way how to measure comfort is to carry out studies with probands. One way of assessing the physiological comfort of the garment is by testing garments under defined conditions. They can be done under real conditions – using clothing in real conditions – or under controlled climatic conditions and activity in a laboratory (Fig.1). Although the first method best reflects the actual usage of clothing, but the evaluation is difficult due to a number of influencing factors. Measurements under controlled conditions have significant advantages. The testing conditions are reproducible and sensors can be connected to the subject's body with the aim to gain objective data (heartbeat, temperature, humidity, etc.) see Fig.2. Using sensors placed in different parts of the body we can monitor the evolution of microclimate in real time in the interlayer interaction of the skin and monitored T-shirts. We can also monitor the subjective feelings of the tested person (proband). The research activity consisted of testing a selected thermo-physiological characteristic affecting the usability of textile materials in terms of user comfort and laboratory testing in a simulated load proband. Experimental work was carried out in the following steps:

- laboratory testing - measuring the temperature and humidity in the interlayer clothing during a continuous loading of the proband,
- laboratory testing - subjective assessment of clothing probands (see [3] for Detailed Information),
- measurement of selected utility properties in the laboratory of physiological comfort.

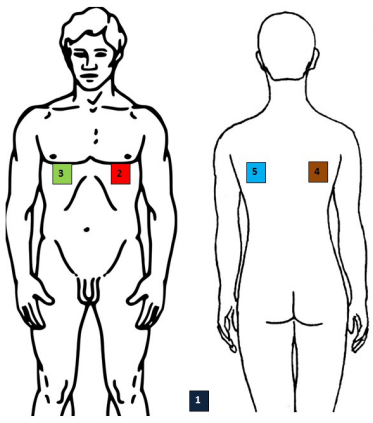

Fig. 1: Test subject while evaluating the 1st layer of clothing in the laboratory of physiological comfort. Fig. 2: The position of sensors for temperature and humidity on to the body.

1.2. The Characteristics of the selected set of T-shirts

1st layer of clothing - the transport layer

The set of T-shirt for testing clothing comfort was selected based on the requirement for optimal physiological comfort both during normal activity and medium weight job, especially in long term moderate loading of organism during fitness training. The selected set of T-shirts so well covers the entire segment of professionals (firefighters, maintenance, police, army, stewards, etc.) and is also suitable for sports activities. It is designed primarily for an environment without the possibility of easy replacement by another piece of clothing, as it is

common in professional sports activities. [4] The first layer may serve as the outer layer of garment, or as in our case, as the top layer of the garment. The Table 1 shows the labelling of samples of clothing that have been selected for testing and their basic and selected material parameters measured relative to the investigated parameters.

Table 1: Material parameters of tested T-shirts.

Marking	Material	PRODUCER / Origin	Structure	Thickness [mm]	Weight [g/m^2]	Air permeability [l/min/m^2]	Resistance against water-vapours R_{et} [m^2.Pa.W^{-1}]	Thermal resistance R_{ct} [m^2.K.W^{-1}]
T-shirt 1	100% CO	KAJA s.r.o / Czech Republic	weft single plain	0.69	170.22	2089.00	2.56	0.019
T-shirt 2	100% WO	DEVOLD MSM / Norway	weft double	0.94	216.85	>12000.00	2.59	0.037
T-shirt 3	100% PP	SPOLSIN s.r.o. / Czech	weft interlock	1.51	189.16	6060.00	5.12	0.046
T-shirt 4	100% PL	ADIDAS / Philippines	weft interlock	0.59	132.19	9750.00	2.00	0.011
T-shirt 5	95%CO/ 5% EL	SPOLSIN s.r.o. / Czech Republic	weft single plated jbutted	0.77	225.69	1620.00	4.15	0.025
T-shirt 6	100% CO	France	weft single plain	0.67	161.17	5057.00	3.06	0.020
T-shirt 7	100% CO	Romania	weft single plain	0.91	220.02	1993.00	3.78	0.017
T-shirt 8	50%CO/50% PL	USA	weft single plain	0.72	153.86	5786.00	3.23	0.024
T-shirt 9	100% CO	Italy	weft single plain	0.69	151.61	5014.00	2.92	0.015
T-shirt 10	50%CO/50% PL	Macedonia	weft single plain	0.67	156.95	6600.00	2.82	0.020
T-shirt 11	100% CO	United Kingdom	weft single plain	0.83	215.89	1294.00	3.38	0.018
T-shirt 12	100% PL	POLARTEC / USA	weft interlock	0.92	179.42	>12000.00	3.14	0.030
T-shirt 13	100% PL	POLARTEC / USA	weft single plated jbutted	0.57	124.17	4170.00	1.30	0.008

1.3. Evaluation of the experiment – objective and subjective

To ensure the test subject's maximum performance and comfort, it is important that the 1st layer of clothing allows provision of the optimum temperature and humidity during the subject's long-term load. The subject's sweat is absorbed by the first layer of clothing and subsequently it is transported to the clothing surface where it starts to evaporate. The shorter the duration of this process, the better the ability of the material and T-shirt structures to absorb, transport and conduct humidity from the body. Illustration (Fig.3 -right) shows tracking the moisture and temperature in the layer between the T-shirt and the skin during the load test for T-shirt No.2. Fig. 3 shows subjective evaluation of the tested T-shirts comfort by proband during the load test.

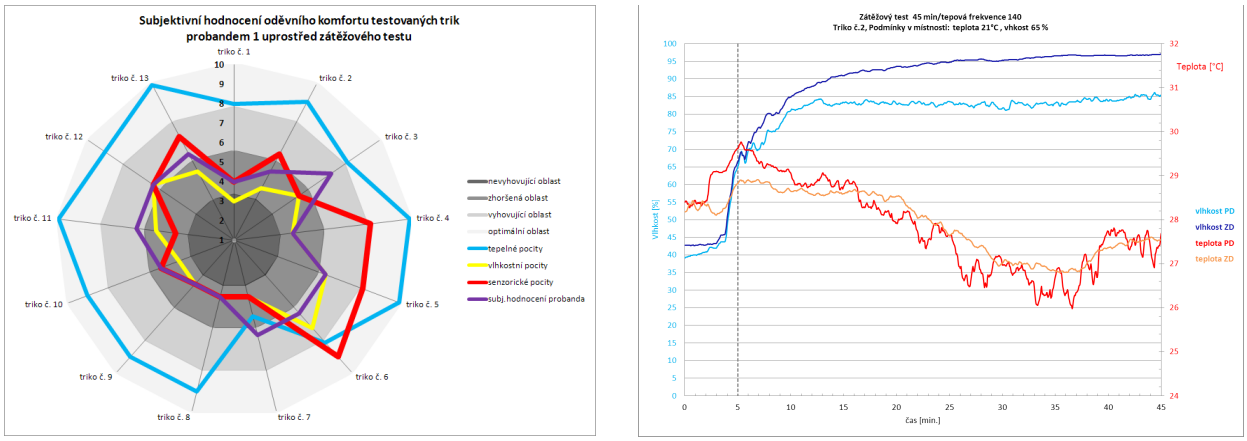

Fig. 3: Illustration tracking the moisture and temperature in the layer between the T-shirt and the skin during the load test for T-shirt No.2. and subjective evaluation of the tested T-shirts by proband during the test.

1.4. Evaluation of selected utility properties

In evaluating the utility properties of clothing materials for working and sporting purposes, a group of properties that directly relate to the physical transmission parameters as, temperature, moisture, etc come to the fore. The following three parameters which influence the subject's physiological comfort with respect to the used materials were chosen for material evaluation: air permeability, thermal resistance R_{ct}, resistance to water vapour R_{et}. On the graph, see Fig.4 shows an example of air permeability evaluation using the normalized index. The resulting index is a dimensionless value obtained by a linear conversion, where the index 1 is the best rating of the given parameter of T-shirts. [5]

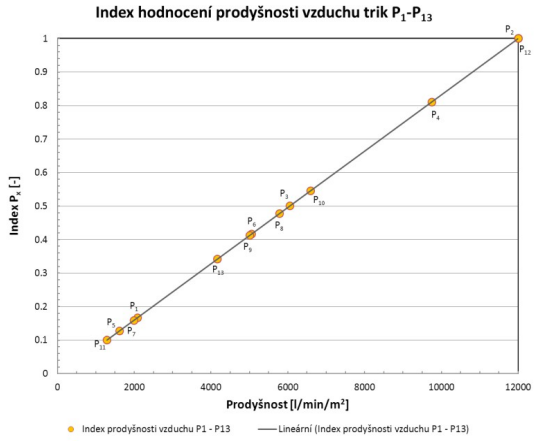

Fig. 4: One side bounded properties – Air permeability index.

Volume porosity was calculated from the material evaluation, (1) and from the measured values, R_{ct} and R_{et} was calculated, according to [2] calculated index of water-vapor permeability (2). The resulting index value of water-vapor permeability I_{mt}=0 is the lowest limit and represents infinite resistance rating, 1 has a thermal resistance to water vapor as the air layer of the same thickness.

$$V_p[-] = 1 - AM/(\rho_f \cdot d)$$

$$I_{mt}[-] = (R_{ct}/R_{et}) \cdot S$$

Where: AM – Areal Mass [kg/m^2], d – Fabric Thickness [m], ρ_f – Fiber Mixture Density [kg/m^3], S – equals 60 [Pa/K].

In the following table, see Table 2, T-shirt are sorted according to the index of water vapor transmission from the worst to the best. Index values equal to or close to 1 represent conditions for achieving optimal state of convenience to the organism. From calculated paired correlation coefficients, it is obvious that the volume porosity for our collection of T-shirt is not relevant for evaluation of clothing comfort.

Table 2: Summary table of normalized indices and selected utility properties.

Marking	water-vapour permeability index I_{mt} [-]	air permeability index [-]	volume porosity [-]
Triko 7	0.27	0.11	0.841
Triko 9	0.31	0.14	0.855
Triko 11	0.32	0.17	0.829
Triko 4	0.33	0.18	0.839
Triko 5	0.36	0.35	0.807
Triko 13	0.37	0.42	0.843
Triko 6	0.39	0.42	0.842
Triko 10	0.43	0.48	0.839
Triko 1	0.45	0.50	0.838
Triko 8	0.45	0.55	0.853
Triko 3	0.54	0.81	0.862
Triko 12	0.57	1.00	0.860
Triko 2	0.86	1.00	0.824

1.5. Summary of the results obtained from the experimental part

T-shirt No.2 achieved the highest index see Tab. 2, but due to the subjective evaluation by probands we have to consider only conditional recommendations, because there is a group of people who are feeling discomfort when they wear T-shirt from natural composition of 100% merino wool. T-Shirt No.12 reached the second highest index and therefore has the best oportunity to achieve the best physiological comfort for users during the long-term stress. Overall evaluation is combination of results from three separate aspects: a subjective evaluation of clothing by proband, monitoring temperature and humidity at a defined load proband in laboratory conditions, the evaluation of selected utility properties. From the obtained and measured results of subjective evaluation and objective evaluation of probands , it is obvious that the most appropriate T-shirt for recreational and fitness sportsmen and for a profession that does not allow a quick change of clothing is T-shirt No.12 from our set of samples.

2. Conclusion

The aim of the research work carried out at the Faculty of Textile TUL was to analyse the requirements for the first layer of clothing and to explore options for quantitative evaluation. Three methodologies were selected for the evaluation- two ways of testing at a defined load proband in laboratory conditions and measurements of selected properties of fabrics that have an impact on physiological comfort of the wearer's clothing. During research work, it was found that these three different evaluation methods are difficult to incorporate into a single complex number, because the comfort of clothing is evaluated from different perspectives. For good evaluation of clothing comfort, it is necessary to consider all three methods. For quick assessment, of course the easiest is to measure properties that affect the physiological comfort of clothes e.g. R_{et}, R_{ct}, λ, air permeability and so on. The overall assessment of comfort of clothing has to also incorporate aspects of design, pattern construction and other aspects, thus making the objective evaluation of clothing so complicated.

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