A NEW INDEX OF THERMAL COMFORT OF SPORT DRESSES AND UNDERWEAR IN WET STATE

Lubos Hes, Vladimir Bajzikand and Ivan Dolezal
Technical University of Liberec, 460 15 Liberec, Czech Republic,

Abstract: *In the study, thermal resistance and water vapour permeability of 12 sport dresses in dry and wet state were determined, and all these values were used for the calculation of the so called dimensionless Wet Comfort Index WCI, which extends from 0 to 1. The maximum value 1 indicates the best thermophysiological comfort level in wet state. Wetting of the dresses was achieved by training of a sportsman on a running simulator. It was found, that for the best sport dresses consisting of special polyester and polypropylene surface grooved fibers, the WCI did not cross the level of 0,2. This surprisingly low level demonstrates the importance of testing of thermal comfort properties of fabrics in wet state by means of special instruments.*

***Keywords*:** *Thermophysiological comfort, sport dresses, wet state*

1. Introduction

Thermal resistance and water vapour permeability of clothes in dry state are considered the most important factors of theirthermophysiological comfort[1]. However, both outerwear and particularly underwear fabrics (T–shirts, dresses) are frequently used in wet state, caused by the sweat condensation and absorbtion. Unfortunately, thermal resistance and water vapour permeability of cheap and costly underwear fabrics and sport dresses in dry state practically do not differ from each to other. Thus, the not informed users buy cheap underwear, which, after being wetted by the absorbed sweat, may cause serious discomfort.

In this study vapour permeability of 12 sport dresses in dry and wet state were determined, and all these values were used for the calculation of the so called dimensionless Wet Comfort Index WCI, which extends from 0 to 1. The maximum value here, 1, should indicate the best thermophysiological comfort level in wet state. Wetting of the dresses was achieved during training of a sportsman on the running simulator. Thermal resistance and water vapour permeability of dry and wet dressed were determined by means of non-destructive Czech fast testing instruments PERMETEST and ALAMBETA, which were described in [2-3].

2. Tested fabrics and the measurement procedure

Table1: Description of the studied samples (some containing 5 - 8% of elastans) wetted by running on the simulator

Code	Composition of dresses	Structure of dresses	Squaremass [g/m^2]	Wetting level [%]
A	PES 62%+PAD+Elastan	Weft single jersey with ribs	185	7,0
B	PES 92%+Elastan	Weft single jersey	218	5,0
C	PES chemical modified	Weft double jersey +single rib 3:2	160	6,2
D	COT 100%	Weft single jersey	192	16,2
E	COT 55%+PAD	Weft interlock (smooth)	184	15,5
F	PES 54%+PES CD	Weft single jersey with loops	174	7,1
G	PAD 56%+POP+Elastan	Weft single jersey	203	5,5
H	POP physically modified	Weft double jersey with loops	95	16,5
I	PES 51%+PES miner. filled	Weft interlock knit	129	12,2
J	PES 50%+COT	Weft double jersey (smooth)	150	12,5
K	PES 79%+PAD+Elastan	Weft single jersey	168	11,5
L	PAD mic 55%+PES+Elastan	Weft double jersey with ribs	214	6,3

The dresses were 2 times washed, and then their thermal properties and water vapour relative permeability (RWVP) under standard (dry state) conditions were determined. The mentioned RWVP here means the ratio between the cooling heat flow passing through the studied fabric inserted in the PERMETEST instrument and the cooling heat flow passing through the measuring head of this instrument without any fabric covering the measuring surface.

Before the following training, the dressed were dried at 110°C (where possible) and weighted. Then the sportsman, wearing one by one the tested dresses, exhibited training under same or very similar climatic conditions (22°C, 36%) and with the same or similar effort (same running velocity 2,8 m/s, same time 20 minutes). After the training the dressed were hermetically closed in boxes and weighted.

a. b. c.

Figure 1: Examples of the tested dresses with 100% polymer content and with long sleeves used for the training: a. Cotton, b. Modified polyester, c. Modified polypropylene

Determination of the effective relative water vapour permeability (effective RWVP) of wetted fabrics is not as easy. The totalheat flow (q_{tot}) transferred through the boundary layer of the fabric surface is given by the sum of heat flow passing from the skin through the permeable fabric $q_{fab\ w}$ and heat flow $q_{fab\ surf}$ caused by temperature gradient between the skin and fabric surface, which is cooled by evaporating of water from the fabric surface

$$q_{tot\ w} = q_{fab\ w} + q_{fab\ surf} \qquad (1)$$

In order to determine the effective RWVP by means of the PERMETEST instrument, it is necessary to execute 2 different measurements on the same sample. In the first step, the relative cooling heat flow $q_{tot\ w}$(Eq. 1) passing through the wetted sample and the generated by the wet sample surface is measured.

In the second step, the measuring head of the PERMETEST instrument is covered by an impermeable foil, which stops the effective relative cooling flow $q_{fab\ w}$ through the wet fabric. Thus, we would determine the relative cooling flow$q_{fab\ w}$ from the wet fabric surface only. The difference between both the mentioned measurements yields the required relative cooling flow$q_{fab\ w}$,whichalso presents the effective RWVP.

Thermal resistance, conductivity and thermal absorbtivity of the dresses in dry state andwet state were determined by the ALAMBETA instrument at the 200 Pa pressure. The wetted dressed were measured in such places, which were subject to intensive sweating during the training. The most uniform sweating takes place in the back part of the body along the backbone.

3. Experimental results and their evaluation

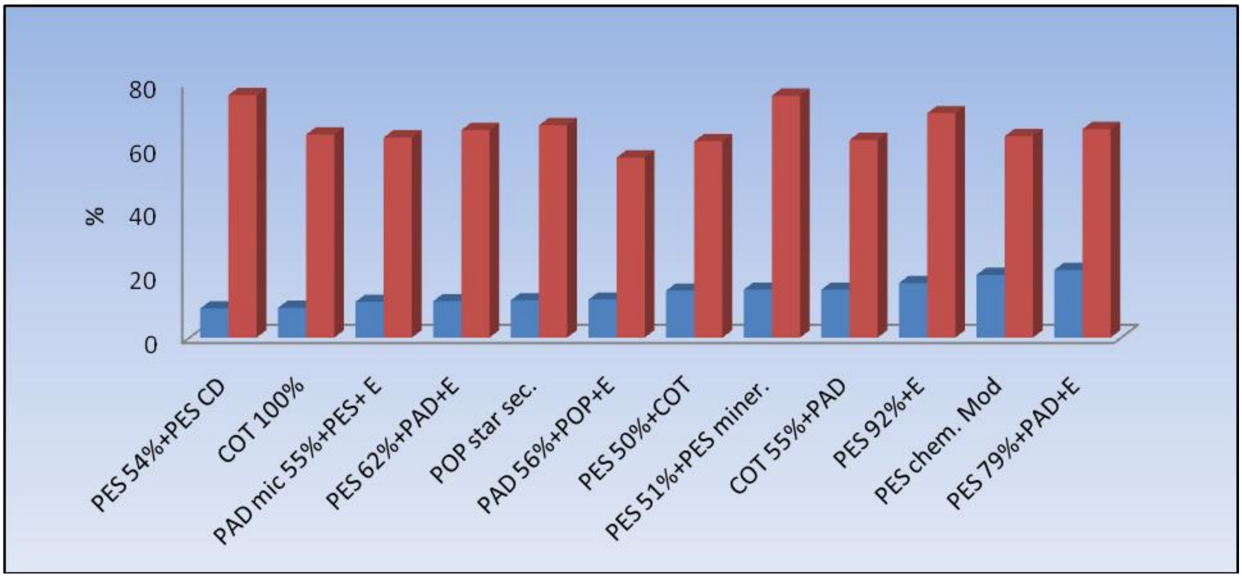

Figure 2: Water vapour relative permeability (RWVP) of the studied dressed inn dry state (inred) andeffective RWVP of the dresses after wetting during the training (in blue)

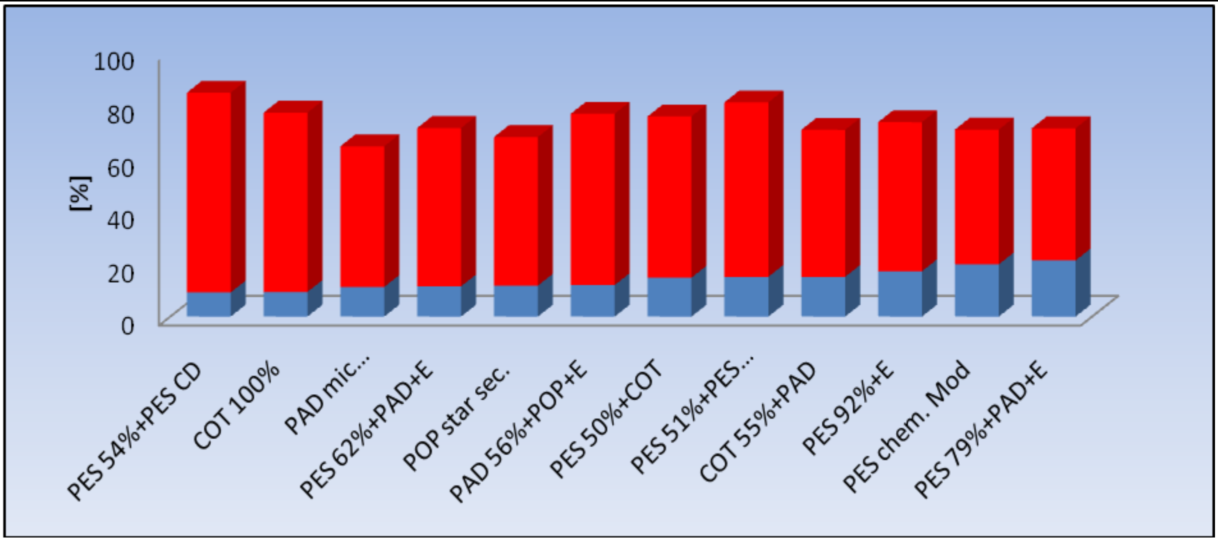

Figure 3: Effective RWVP of the studied dresses in wet state (in blue) and relative cooling heat flow $q_{fab\ surf}$
From the wet fabric surface (in red)

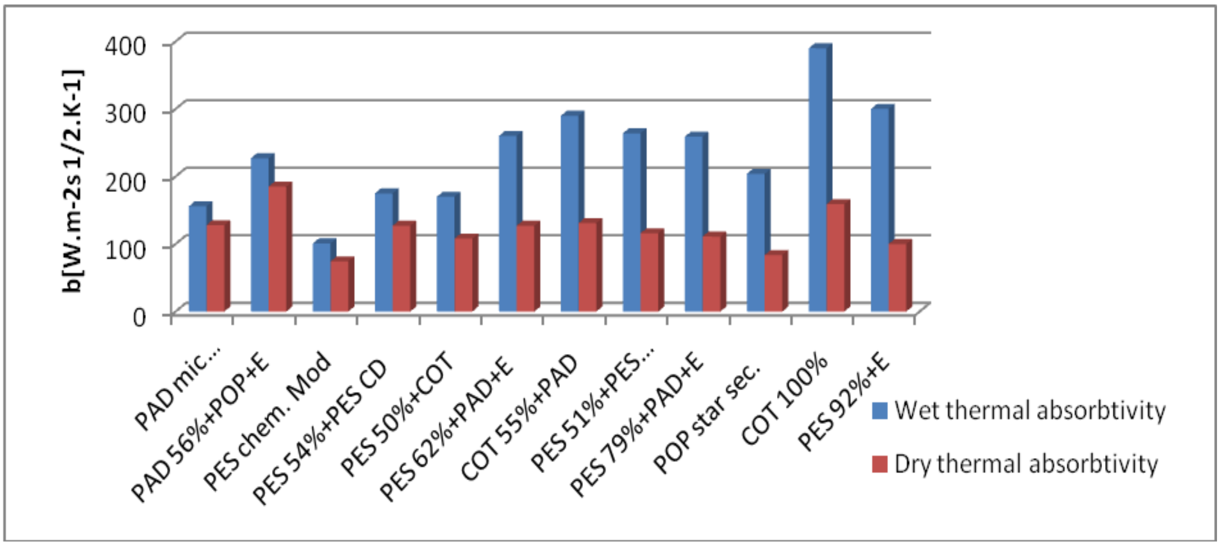

Figure 4: Thermal absorbtivity of dresses in dry state and after their wetting during training on the running simulator

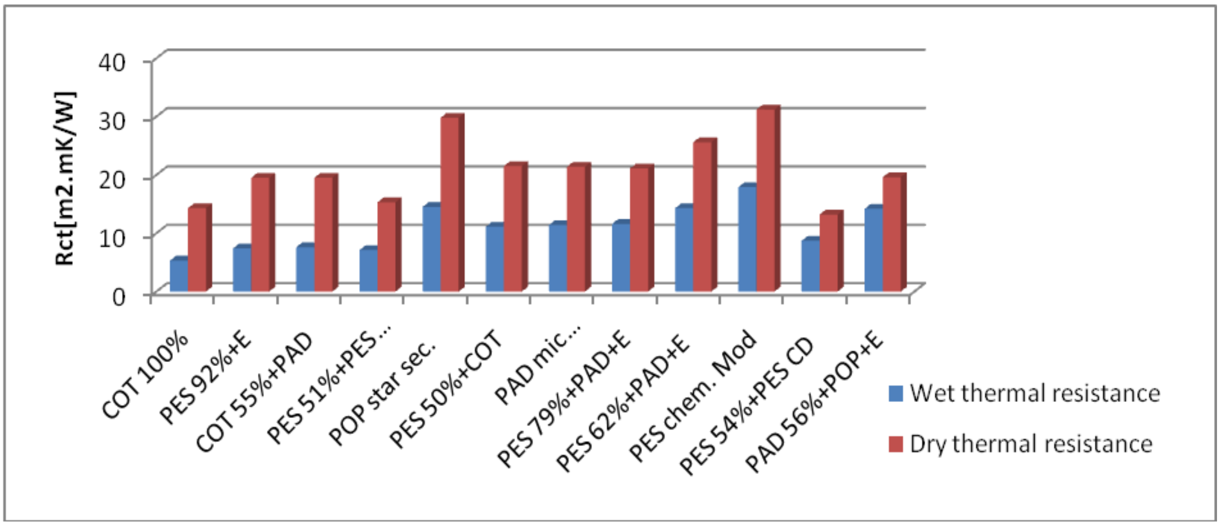

Figure 5: Thermal resistance of dresses in dry state and after their wetting during training

From the presented results follows, that the effective RWVP of the wetted dresses exhibit very low values. Should the wet dress not be the direct contact with skin, the cooling flow resulting from the water evaporation from the wet fabric surface may not contribute to the skin cooling, and most of the cooling effect gets lost.

As regards thermal resistance of the dresses wetted during the training, this important parameter in our case dropped to 30 – 70% of the original (dry) values. Thermal absorbtivity of the studied dresses, due to their wetting, increased by 30-190%, where the last value already presents quite unpleasant, cold feeling.

The presented results confirm, that both effective RWVP and thermal resistance of dresses, wetted during the real sport activity, decreases substantively. This decrease is specific for dresses of various composition and structure. The best dresses exhibit in wet state the highest values of the mentioned ERVWP and thermal resistance (or $RWVP_w$and R_w). To characterise the effect of moisture on thermophysiological comfort of underwear and sport dresses, a new so called Wet Comfort Index (WCI) was introduced, as follows:

$$\mathbf{WCI = (RWVP_w \,.\, R_w) / (RWVP_d \,.\, R_d)}$$

This index level extends from 0 to 1. WCI of the best underwear and sport dresses will approximate to the 1 value. The WCI levelof the studied dresses is shown in the next **Figure.6.**

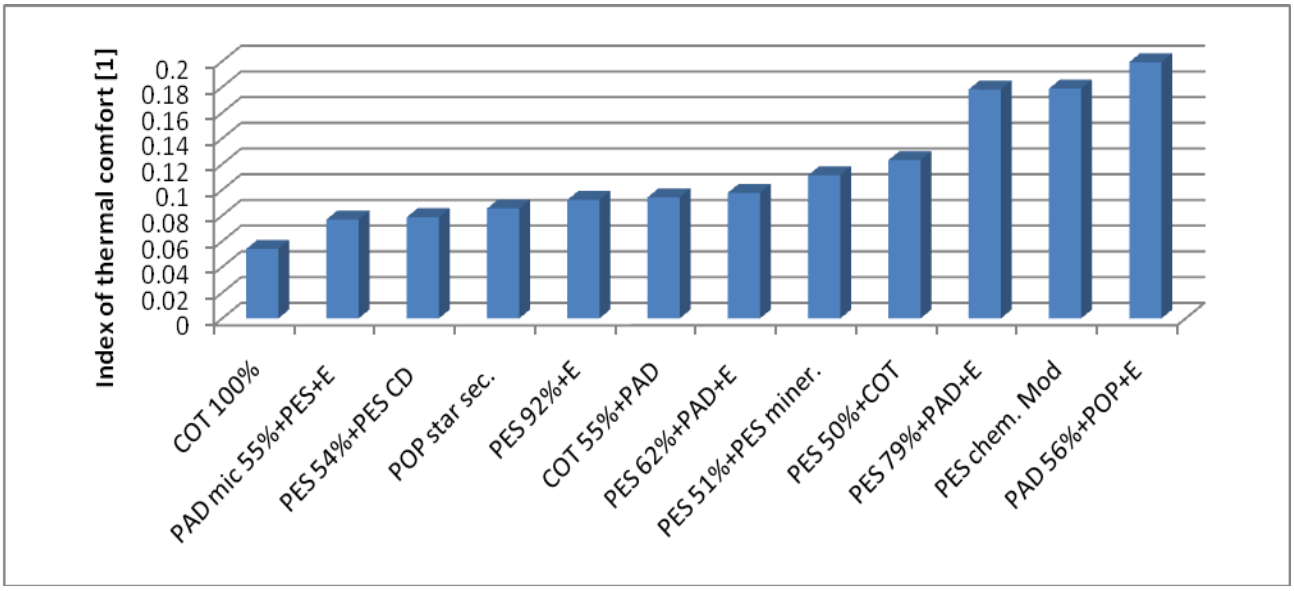

Figure 6: The Wet Comfort Index of the studied dresses wetted during training on the running simulator

4. Conclusions

In the study, thermal resistance and water vapour permeability of 12 sport dresses in dry and wet state were determinedand used for the calculation of the Wet Comfort Index.The best levels of WCI exhibited the dress G(56% polyamid, 39% polypropylen, 5% elastan) followed by the dress C (100% chemically modified PES) and K (79% polyester, 12% polyamid, 9% elastan). The worst properties in wet state were found for the dress D (100% cotton), and then dresses L (55% micro nylon, 40% micro polyester, 5% spandex) and F (54% polyester, 46% polyester Cooldry). From the study follows thatthermophysiological comfort properties of underwear or dresses in dry statecanbe substantially lower than their comfort properties in real conditions in their use due to the absorbed sweat. This surprising observation emphasizes the importance of testing of thermal comfort properties of fabrics in wet state by means of special instruments.

References

[1] Gibson, P. W.: *Factors influencing steady-state heat and water-vapour transfer measure for clothing materials*, *Textile Research Journal,* **Vol.** 63(1993), No.12, pp. 749-764, ISSN1746-5175

[2] Hes, L.;Araujo, M.: *Simulation of the Effect of Air Gaps between the Skin and a Wet Fabric on Resulting Cooling Flow. Textile Res. Journal*,**Vol.** 80(2010), No. 14, pp. 1488–1497, ISSN1746-5175

[3] Hes, L; Lizak, P.: *Thermal comfort of biking dresses at real conditions of their use*.*Proceedings ofFiberSociety SpringConference*,Hufenus R. (Ed.), pp. 39-40, St. Gallen, May 2012, EMPA, St. Gallen (2012)

[4] Hes, L.;Dolezal, I.: *The effect of moisture on water vapour permeability of semi-permeable fabrics, Proc. of AUTEX 2009 World Textile Conf.*,Kumbasar P. (Ed), pp. 714-723,May 2009, EGE Univ., Izmir (2012)

[5] Bogusławska-Bączek M.;Hes L.:*EffectiveWaterVapour Permeability of Wet Wool Fabrics and Blended Fabrics,*F*ibres&Textilesin EasternEurope,* **Vol.**21 (2013) No. 1(97), pp. 67-71, ISSN 1230-3666

[6] Povysil M.: *MSc Thesis* (in Czech), Technical University of Liberec, Liberec, (2014).

5. Corresponding Address

Lubos Hes,
Technical University of Liberec,
460 15 Liberec, Czech Republic.