INTERACTION BETWEEN THE HUMAN BODY AND TEXTILES

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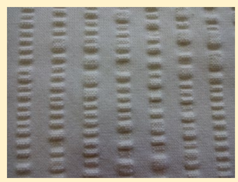
Human body is in permanent contact with textile materials. Fabrics can affect a human organism and cause the negative or positive effects. On the other hand the human body affects a clothing. E.g. liquid sweat absorbed from human skin causes the changes in the thermal insulation of the material from which the clothing is made. Another example: stiff and rough fabrics can give mechanical impact (micro-massage) on human skin. At the same time friction between the skin and fabric as well as pressure on the material, e.g. when sitting, may cause deformation of the fabric surface. It can change the surface geometry of the fabric and the properties resulted from the surface geometry such as wetting ability.

EXPERIMENTAL

Transport of liquid moisture and **surface geometry** of the seersucker woven fabrics have been investigated. The fabrics have been made of the same set of warps (20 tex x 2 CO) and different weft yarns:

- 20 tex x 2 cotton yarn (**F1**),
- 15 tex x 2 CO50/PES50 (**F2**),
- 15.6 tex x 2 PES 156/94/2 ThermoCool Fresh (**F3**),
- 12 tex x 2 PES 88 Drirelease/ SeeCell Active (**F4**).



Exemplary seersucker woven fabric

Moisture Management Tester

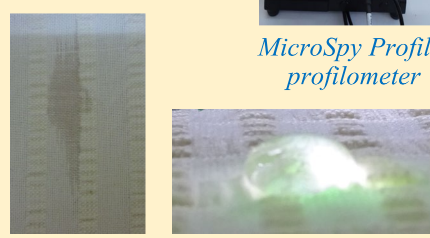
MicroSpy Profile profilometer

RESULTS

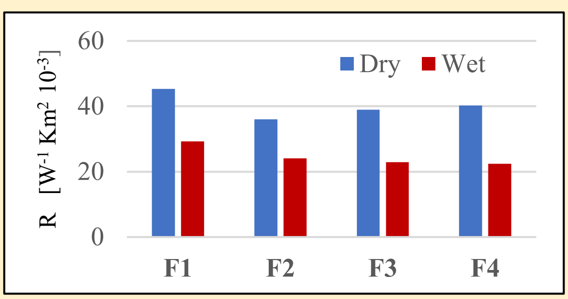
Moisture transport ability measurement acc. to MMT

Fabric	ART %/s	ARB %/s	OMMC	Classification
F 1	79.3	14.1	0.187	Fast absorbing slow drying
F 2	268.1	50.2	0.020	Water repellent
F 3	448.5	0	0	Water proof
F 4	394.1	0	0	Water proof

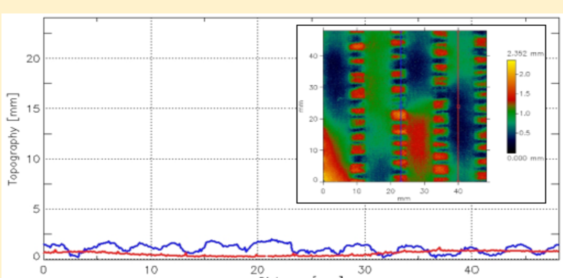
ART *– Absorption rate for top surface,* ***ARB*** *– absorption rate for bottom surface,* ***OMMC*** *– overall moisture management capacity.*



*Absorbed (**F1**)and not absorber(**F3**) drop of testing solution on the top fabric surface*



Thermal resistance in dry and wet state



Exemplary profiles of puckered (blue) and flat (red) strips of the seersucker woven fabric

CONCLUSIONS

On the basis of the results from the MMT device it was stated that only the fabric F1 transports the liquid moisture from the top to bottom surface. It was classified as a fast absorbing and slow drying. It was also confirmed that the liquid moisture content changes the thermal resistance of the fabrics being the object of the investigations. In all cases thermal resistance of the fabrics in wet state is significantly lower than the thermal resistance of the fabrics in the dry state.

Interaction between the human body and textiles or clothing can have different forms. It can be one-way or two-way effect. Transport of liquid moisture in the textile materials can affect a physiological comfort of human being but also can influence a heat exchange between the body and surrounding. New measuring devices and systems are developed which make possible to assess the textile materials from the point of view of their ability to liquid moisture absorption and transport in different directions. However, in order to assess completely the fabrics in this aspect apart from the MMT measurement it is necessary to measure the drying rate of the textile materials.

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ABSTRACT
Human body is in permanent contact with different kinds of textile material. Usually, there are different apparel goods, underwear or bed linen which touch the human skin and can cause different: positive or negative effects. Cotton fibres and textile products made of them are considered as friendly to the human skin. It is due to the excellent inherent hygienic properties of cotton fibres. However, comfort-related and tactile properties of the textile materials depend not only of the raw material composition but also on the structure of the materials.
In the presented work different textile materials made of cotton and blends of cotton with other fibres were measured in the range of their properties influencing the comfort and well-being of user of clothing made of these materials. Measurement was performed in the range of thermal properties, liquid moisture transport and surface properties of selected cotton-based textile products.

INTRODUCTION
Human body is in permanent contact with different kinds of textile materials. Usually, there are various apparel goods, underwear or bed linen which touch the human skin and can cause different: positive or negative effects. Different textile materials used in clothing, underwear or bedclothes are in direct contact with the human body, especially skin. Due to this fact the textile materials can affect a human organism and cause the negative or positive effects. Among the negative effects of textile material affecting on the human skin there should be mentioned here:

- mechanical irritation,
- chemical irritation,
- hazards of electrostatic discharge and others [Fracczak 2017, Fracczak 2019].

The problem of negative affecting the human skin by textile materials concerns mostly the people with sensitive or oversensitive skin. In majority there are people suffering different skin diseases such as: eczemas, especially atopic dermatitis, psoriasis, shingles, lyme disease and others. Symptoms of the mentioned skin diseases are: long-lasting and recurrent bearing, itching, dry skin and increased skin stretching. The mechanical irritation of the human skin by the textile materials depend on the mechanical properties of the materials directly adjoining the skin. Surface friction, surface roughness and fabric stiffness should be listened as the most important properties of textile materials from the point of view of skin irritation.
Mentioned above surface properties can be also utilized in such a way to have a positive impact of human body. For instance, the fabrics of high surface roughness, bending stiffens and friction can be applied in clothing ensuring multimessage effect [Matusiak 2012].

Positive or negative effect of clothing on the human body is one-way effect. However, there are also textile materials which interact with the user's body.
Interaction is a kind of action that occurs as two or more objects have an effect upon one another. The idea of a two-way effect is essential in the concept of interaction, as opposed to a one-way causal effect.
Smart textiles can be an example of the textile materials which interact with human body or environment. Smart textiles, called also as intelligent textiles, are: “.. able to sense stimuli from the environment, to react and to adapt to them by integration of functionalities in the textile structure” [Van Langenhove 2005]. The stimulus can be different, usually thermal, electrical and others. In the group of intelligent textiles the following should be mentioned here:

- textiles containing phase change materials (PCMs),
- shape memory materials,
- thermochromic materials,
- photochromic materials,
- far infrared materials (FIR)

and many others.

It is possible to show many examples of smart textiles mentioned above. Some of them are still in development stage, some others have found already a practical application. However, an interaction between the human body and textiles concerns not only so called smart textiles. In the case of standard textile materials and products it is possible to show the two-way effects. For example, clothing with high thermal insulation may cause more intensive sweating [Chinta 2013]. Part of sweat in the form of water-vapor is evaporated away by clothing. The rest of the sweat condenses on the human skin and is absorbed by the clothing material. Absorbed liquid sweat causes changes in the thermal insulation of the material from which the clothing is made.
In the example given above, sweat in a form of water-vapor is released from the space between the human body and clothing but sweat in liquid form remaining in clothing material changes the comfort of clothing usage influencing the phenomenon of heat and moisture exchange between the human organism and surrounding.
Another aspect of the interaction between the human body and clothing is massaging the human skin by the clothing inner surface adhering the skin. Especially, the stiff and rough textile materials can give mechanical impact on human skin. However, when using clothing, friction between the skin and the material as well as pressure on the material, e.g. when sitting, may cause deformation of the surface of the clothing. It can change the surface geometry of the fabric and in the same way the properties resulted from the surface geometry such as wetting ability.

EXPERIMENTAL

In the frame of presented work a transport of liquid moisture in the typical seersucker woven fabrics has been investigated.
The fabrics have been made of the same set of warps and different weft yarns. Investigated fabrics were manufactured on the basis of two warps: warp I – basic and warp II – puckering, both made of the 20 tex x 2 cotton yarn. Four kinds of yarn were applied in weft. There were:

- 20 tex x 2 cotton yarn,
- 15 tex x 2 CO50/PES50,

- 15.6 tex x 2 PES 156/94/2 ThermoCool Fresh multifilament yarn,
- 12 tex x 2 PES 88 Dri*release/* SeeCell Active 12.

The seersucker fabrics were manufactured on a loom with two beams. Next, the fabrics were finished by the same way including washing, drying and stabilization processes. The basic structural parameters of the investigated fabrics are presented in Table 1.

Table 1. Characteristic of the manufactured seersucker woven fabrics

Parameter	*Unit*	*Value*			
		Fabric 1	*Fabric 2*	*Fabric 3*	*Fabric 4*
Warp I	-	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO
Warp II	-	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO
Weft	-	20 tex x 2 CO	15 tex x 2 CO50/ PES50	15.6 tex x 2 PES 156/94/2 ThermoCool Fresh	12 tex x 2 PES88/Dri Release SeeCell Active12
Weave – warp I	-	plain	plain	plain	plain
Weave – warp II	-	rep 2/2	rep 2/2	rep 2/2	rep 2/2
Mass per square meter	gm^{-2}	241	224	201	208
Warp density	dm^{-1}	278	281	284	274
Weft density	dm^{-1}	221	237	290	281
Thickness	mm	1.64	1.41	1.31	1.49

The fabrics were measured in the range of the thermal insulation properties. Measurement was performed using the Alambeta device according to the Internal Standard No. 23-204-02/01. The measurement was done in dry and wet state of the fabrics. The comparison of the thermal insulation of the fabrics in dry and wet state is presented in Fig. 1.
It is clearly seen that the moisture content changes the thermal resistance of the fabrics being the object of the investigations. In all cases thermal resistance in wet state is significantly lower than the thermal resistance of the fabrics in the dry state. The lowest difference between the thermal resistance of fabrics in dry and wet state occurred for the fabric No. 2 with the 15 tex x 2 CO50/PES50 yarn as a weft.
Obtained results showed an importance of moisture transport for a thermal resistance of fabrics and thermal comfort of clothing user. Due to this fact next stage of the investigation was to measure an ability of fabrics to liquid moisture transport. The measurement was performed using the Moisture Management Tester M 290 T (Fig. 1) by SDL Atlas according to the device manual based on the AATCC Method 195 -2011.

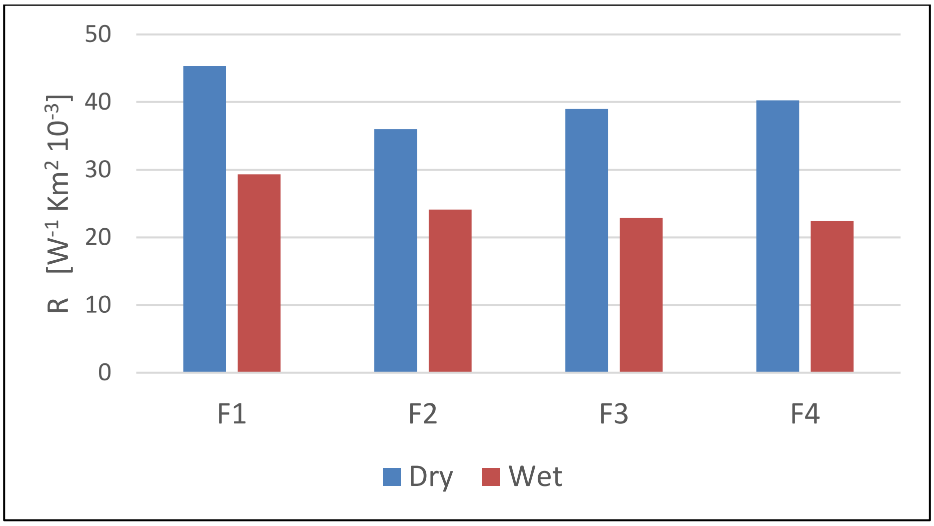

Figure 1. The comparison of the thermal insulation of the seersucker woven fabrics in dry and wet state

Figure 2. Moisture Management Tester

The Moisture Management Tester (MMT) is an instrument designed to measure the dynamic liquid transport properties of textiles such as knitted and woven fabrics in three aspects [Matusiak 2019]:

- absorption rate – moisture absorbing time for inner and outer surfaces of the fabric,
- one-way transport capability – one-way transfer of liquid moisture from the inner surface to outer surface of fabric,
- spreading/drying rate – speed of liquid moisture spreading on the inner and outer surfaces of fabric.

Device provides the values of 10 different parameters characterizing the liquid moisture transport in the fabric. On the basis of the values of measured parameters the system distinguishes seven major types of fabrics:

- water proof,

- water repellent,
- slow absorbing and slow drying,
- fast absorbing and slow drying,
- fast absorbing and quick drying,
- water penetration fabric,
- moisture management fabric.

The results from the MMT results are presented in Table 2.

Table 2. Results of moisture transport ability measurement by means of the MMT

Fabric	ART %/s	ARB %/s	OMMC -	Classification
F 1	79.3	14.1	0.187	Fast absorbing slow drying
F 2	268.1	50.2	0.020	Water repellent
F 3	448.5	0	0	Water proof
F 4	394.1	0	0	Water proof

Legend:
ART – Absorption rate for top surface,
ARB – absorption rate for bottom surface,
OMMC – overall moisture management capacity.

On the basis of the results from the MMT device it was stated that only the fabric No. 1 transports the liquid moisture from the top to bottom surface. It was classified as a fast absorbing and slow drying. In other cases the fabrics were classified as water repellent or water proof. It was a little surprising because samples No. 3 and 4 contains high performance fibres: ThermoCool and Dri*Release*. Both are considered as the moisture management fibres. Probably the structure of the fabrics being investigated plays a crucial role in the phenomenon of liquid moisture transport from the top to bottom surface of the fabrics. The wetting angle between the water drop and the surface is largely determined by surface topography. Generally, the smoother the surface, the smaller the contact angle (Fig. 3) and in the same way the better wetting ability of fabric.

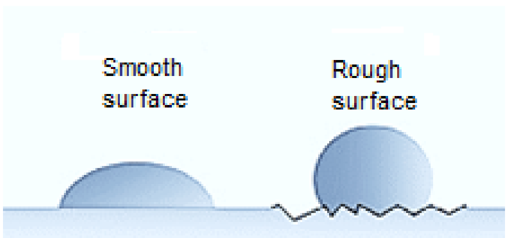

Figure 3. Relationship between the surface and wetting angle

In the case of the seersucker woven fabrics being investigated samples for measurement have been cut in such a way that the puckered strip was in the centre of the sample. It caused that the drops of the testing solution delivered by the pump drip centrically onto the puckered strip of the tested specimen. The surface of the seersucker woven fabric in the frame of puckered area is rough. It was confirmed by measurement the surface geometry of the fabrics by means of the MicroSpy® Profile profilometer by the FRT the art of metrology ™. Figure 4 b presents the profile of the fabric No. 4 created across the puckered strip in place presented in figure 4 a.

a)

b)

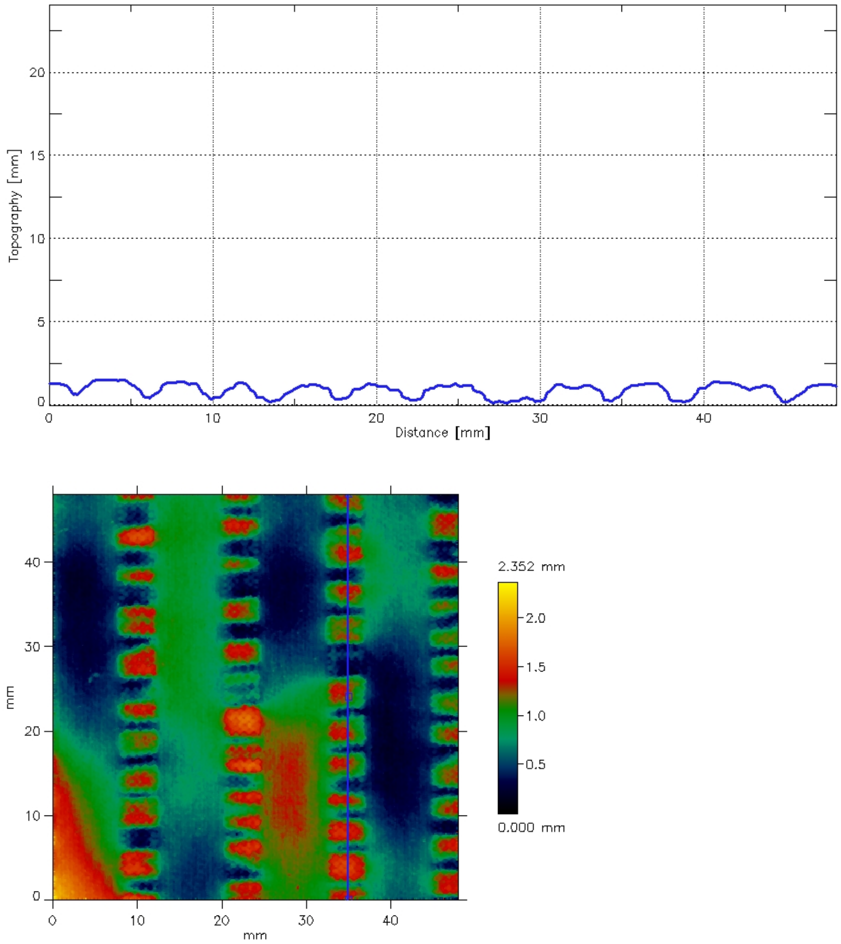

Figure 4. Results from the profilometer: a) profile of the puckered surface of the fabric No. 4, b) placement of the created profile

It is clearly seen that the surface along the crated profile is rough. It causes low wetting ability of fabric in the range of the puckered area. Investigations showed that the flat area of the seersucker fabric is characterized by smooth surface and much better wettability than the puckered area. However, clothing made of the seersucker woven fabrics is in contact with human skin in the puckered places. It means that liquid sweat released by human skin is firstly picked up by the fabric in places created by the puckered strips. In my opinion the problem needs further investigations.

All investigated fabrics are characterized by high absorption rate for top surface. It is surface which adheres to the human skin while clothing usage. Liquid moisture in not transported to the outer (bottom) surface. It causes that the moisture (sweat) is not evaporated outside to the surroundings. Only in the case of the fabrics No. 1 No. 2 a small absorption rate was observed on the bottom surface. While measuring the samples No. 3 and No. 4 the bottom (outer) surface of fabrics remained dry and the testing solution condensed on the inner surface (Fig. 5 a). In the case of sample No. 1 and No. 2 liquid was spread on the fabric surface (Fig. 5 b).

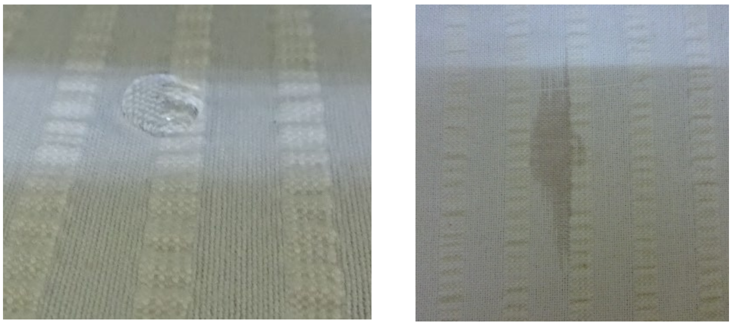

Figure 5. Drop of testing solution on the top surface of the fabric: a) No. 3, b) No 1

CONCLUSIONS

Interaction between the human body and textiles or clothing can have different forms. It can be one-way or two-way effect. Transport of liquid moisture in the textile materials can affect a physiological comfort of human being but also influence a heat exchange between the body and surrounding. New measuring devices and systems are developed which make possible to assess the textile materials from the point of view of their ability to liquid moisture absorption and transport in different directions. However, in order to assess completely the fabrics in this aspect apart from the MMT measurement it is necessary to measure the drying rate of the textile materials.

ACKNOWLEDGEMENT

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