Transport wilgoci w dzianinach w stanie swobodnym i rozciągniętym

Moisture transport in relaxed and stretched knitted fabrics

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Abstrakt
Transport wilgoci w materiałach tekstylnych jest istotny z punktu widzenia komfortu fizjologicznego. Wiąże się to z poceniem się ludzkiego ciała i odprowadzaniem potu z przestrzeni pododzieżowej. Pot może mieć postać pary i/lub płynu. Z tego względu w celu scharakteryzowania materiałów włókienniczych z punktu widzenia transportu wilgoci konieczne jest przeanalizowanie obu zjawisk: transportu wilgoci w postaci pary oraz transportu wilgoci w postaci cieczy. Celem prezentowanej pracy była analiza transportu wilgoci w dzianinach. Pomiaru dokonano za pomocą przyrządu MMT M290 firmy SDL Atlas Ltd. (USA). Dzianiny badano w stanie swobodnym i rozciągniętym. Rozciąganie próbek przeprowadzono za pomocą przyrządu MMT Stretch Fabric Fixture, które jest uzupełnieniem przyrządu MMT M290. Uzyskane wyniki potwierdziły, że rozciąganie poprawia właściwości użytkowe badanych dzianin w aspekcie transportu wilgoci. Dodatkowo stwierdzono, że splot dzianin wpływa zarówno na transport wilgoci w badanych dzianinach, jak i na zmiany zdolności do transportu wilgoci przez dzianiny wywołane rozciąganiem.

Abstract
Transport of moisture in the textile materials is important from the point of view of the physiological comfort. It is connected with the sweating of human body and evaporation of sweat from the space between the human body and clothing. The sweat can be in the form of vapor and/or in the form of liquid. Due to this fact, in order to characterize the textile materials from the point of view of the moisture transport it is necessary to analyse both phenomena: transport of moisture in the form of vapor and transport of moisture in the form of liquid. The aim of presented work was to analyse the liquid moisture transport in the knitted fabrics. Measurement was done using the MMT M290 device by the SDL Atlas Ltd. (US). The fabrics were measured in the relaxed and stretched state. Stretching the samples was done using the MMT Stretch Fabric Fixture device, which is supplementary to the MMT M290. Obtained results confirmed that stretching improves the performance of the investigated knitted fabrics in the aspect of the liquid moisture transport. Additionally, it was stated that weave of the knitted fabrics influence both the transport of liquid moisture in the knitted fabrics being tested and the changes of the liquid moisture transport ability of the knitted fabrics caused by stretching.

Słowa kluczowe: komfort fizjologiczny, dzianiny, pomiar, transport wilgoci
Keywords: physiological comfort, knitted fabric, measurement, moisture transport

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1. Introduction

Transport of moisture in textile materials is very important for physiological comfort of clothing usage. Human body produces sweat permanently. The intensity of sweating depends on different factors such as:

- climatic conditions – temperature, humidity, air movement,
- a kind and intensity of human activity,
- features of human body, i.e. age, gender, weight, metabolic rate, etc.,
- clothing – number of layers, thickness, raw material composition, comfort-related properties of fabrics crating particular layers, etc.

Sweating is a mechanism of thermoregulation of human body. It is a component of thermal balance of human body [1, 2]. The sweat can occur in the form of vapour and liquid. Especially, when sweating is intensive and sweat cannot be evaporated some amount of sweat condenses on the human skin. It is important to transfer the liquid sweat from the human skin through the clothing to the environment. In this phenomenon the clothing is a barrier which can limit the liquid transport. In order to ensure the physiological comfort of clothing usage it is very important to apply the appropriate materials in clothing, especially in the inner layer of clothing. The material of the clothing layer adjacent to the wearer's skin should ensure the effective water-vapor permeability and liquid moisture transport while remaining dry. For years, cotton fibres have been considered as a suitable raw material for use in underwear and clothing due to the excellent inherent hygienic properties resulted from the hygroscopicity of cotton. However, the cotton fibres absorb water becoming wet and unpleasant in touch. The absorption of water is only one of the phenomena involved in the liquid transport in textile materials. Wicking is another process of liquid transport in textiles. It is a spontaneous flow of a liquid driven by capillary forces in pores existing in fabric structure [3, 4]. The wicking can only occur when a liquid wets fibres assembled with capillary spaces between them. The wicking in textile materials is a very complex phenomenon. Generally, we should consider the vertical and horizontal wicking [5, 6].

In order to assess the textile materials from the point of view of the liquid moisture transport, different measurement procedures are applied such as: horizontal wicking test, vertical wicking test and contact angle test. The mentioned methods allow to evaluate individual aspects of moisture transport in fabrics. However, they do not allow for a comprehensive characterization of this phenomenon. For this purpose, the Moisture Management Tester (Fig. 1) has been developed by the SDL Atlas Ltd. (US). The instrument makes it possible to assess the textile materials in the aspect of liquid transport in a complex manner. The MMT M290 is an instrument designed to measure the dynamic liquid transport properties of textile materials in three aspects [1, 2, 7 – 9]:

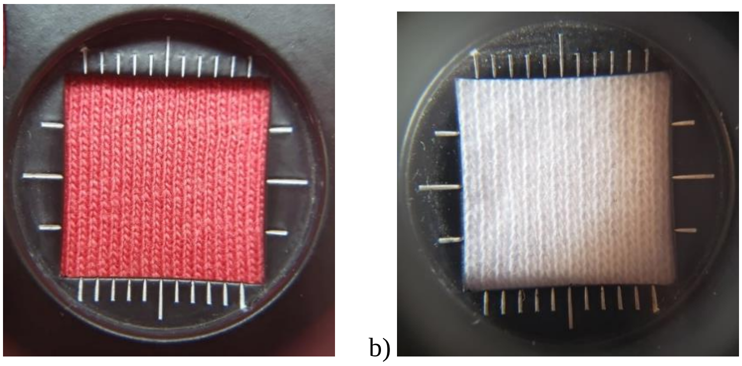
- moisture absorbing time for inner and outer surfaces of the fabric,
- one-way transfer of liquid moisture from the inner surface to outer surface of fabric,
- of liquid moisture spreading on the inner and outer surfaces of fabric.

Fig. 1. The Moisture Management Tester M290 by the SDL Atlas Ltd.

Application of the MMT makes it possible to characterize in a complex way the textile materials in the aspect of their liquid moisture transport ability. The aim of presented work was to analyse the transport of liquid moisture in the knitted fabrics which can be applied in the underwear. Due to the fact that the knitted fabrics are stretchable and very often the clothing made of them is worn in the stretched form, the assessment of the liquid moisture transport in the investigated fabrics has been performed for the samples in the relaxed and stretched form.

2. Materials and methods

Two variants of the knitted fabrics were the objects of the investigations (Fig. 2). They were the cotton fabrics of the single jersey and the 1 x 1 rib stitch. The basic properties of fabrics are presented in the Tab. 1.



a) b)

Fig. 2. Pictures of the investigated knitted fabrics: a – KF1, b – KF2.

Tab. 1. Basic properties of the investigated fabrics.

Knitted Fabric (colour)	Content, %	Thickness, mm	Mass per square meter, gr/m^2	Number of courses/cm	Number of wales/cm
KF1 (red)	100% cotton	0.47	161.09	22	16
KF2 (white)	100% cotton	0.61	138.59	17	12

Measurements have been done using the MMT M290 device using the procedure described in the MMT M290 manual [10]. The procedure is in agreement with the AATCC Method 195 -201 standard [11]. In the method the inner – upper surface of fabric means the surface which adheres to the user's skin while wearing the clothing. According to the standard for each investigated fabric 5 repetitions are performed for fabric samples in square shape 5 cm x 5cm. Moisture management properties of fabrics are evaluated by placing a fabric sample between two horizontal (top and bottom) electrical sensors, each with seven concentric pins (Fig. 3).

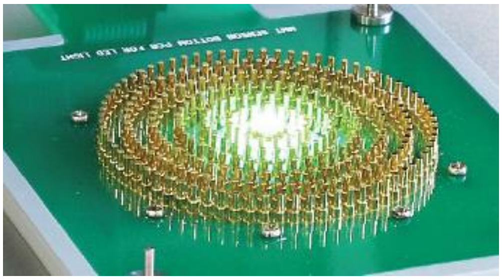


Fig. 3. The bottom sensor of the MMT with the concentric pins.

During the test a pre-defined amount of test solution (synthetic sweat) is introduced onto the upper side (skin side) of the fabric, and then the test solution is transferred onto the material in three directions (Fig. 4).

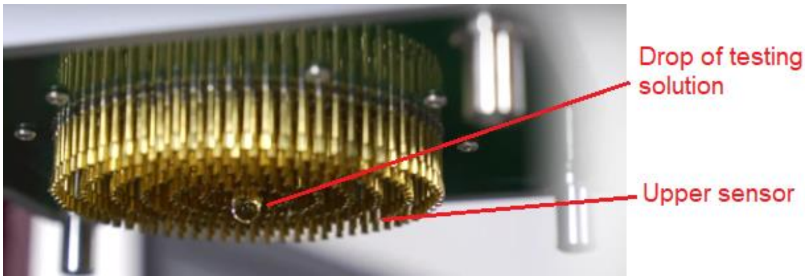


Fig. 4. The upper sensor of the MMT with the drop of the testing solution.

Measurement is performed in standard climatic conditions: 65 ± 5 % RH and 20 ± 2 °C ambient temperature. The test procedure takes 20 min. The MMT measures and records the changes in electrical resistance of specimen due to the changes in liquid content. Next, the parameters characterizing the liquid moisture transport are calculated by the MMT software according to the appropriate algorithms. The following parameters are determined:

- for the top (T) and bottom (B) surface of the fabric:
  - wetting time: WTT and WTB; in [s],
  - absorption rate: TAR and BAR; in [%/s],
  - maximum wetted radius: MWRT and MWRB; in [mm],
  - spreading speed: TSS and BSS; in [mm/s],
- and general parameters for whole fabric:
  - accumulative one-way transport index R; [-],
  - overall moisture management capacity (OMMC); [-].

On the basis of the results the MMT software classifies the measured fabrics into the appropriate type from the waterproof fabric till the moisture management fabric. The fabric is also classified according to the value of particular parameters to the grade from 1 to 5. Higher grade means better performance of the fabric in the aspect of the liquid moisture transport. In the MMT software there are also available different graphs which illustrate the changes of water content in the measured fabric. In order to stretch the samples by a certain size the MMT Stretch Fabric Fixture device [12, 13] was applied (Fig. 5).

Fig. 5. The MMT Stretch Fabric Fixture device.

The round sample of 140 mm diameter is placed on the table of the device, stretched to the percentage required and next locked in the fabric clamp. The excess fabric beyond the clamp circumference is trimmed. The sample prepared in such a way is placed in the M290 MMT test area (Fig. 6).

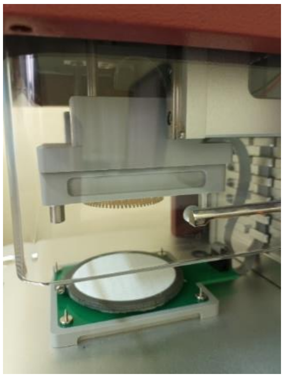


Fig. 6. Stretched sample placed in the measuring area of the MMT.

The device enables to extend the fabric precisely to different sizes from 15 % each 5 % to 50 %. In presented investigations the stretch percentage of 15 % was applied.

3. Results and discussion

The results of measurement of the relaxed and stretched fabrics using the MMT device are presented in the Tab. 2 .

Tab. 2. Results from the MMT for the relaxed and stretched fabrics.

Sample	State	WT T	WT B	TAR	BAR	TSS	BSS	R	OMMC
		s	s	%/s	%/s	mm/s	mm/s	-	-
KF 1	Relaxed	55.52	6.48	245.49	50.85	0.24	0.80	424.31	0.41
	Stretched	97.42	29.18	28.92	57.05	0.14	0.60	690.39	0.54
KF 2	Relaxed	53.69	74.47	228.50	29.65	0.32	0.32	-59.64	0.27
	Stretched	120.00	6.12	0	67.06	0	1.61	1091.9	0.72

On the basis of the results it was stated that the fabrics differ between each other in the aspect of their liquid moisture transport properties. Both fabrics are made of cotton but they have different weaves and basic structural parameters. The wetting time (Fig. 7) of the tops surface of samples in the relaxed state is similar for both investigated fabrics: 55.52 s for the KF 1 fabric and 53.69 for the KF 2 fabric. In the case of the bottom surface the wetting time of the fabric KF 2 (rib stitch) in the relaxed state is significantly higher -74.47 s than that for the KF 1 fabric (single jersey) – 6.49 s. After stretching by the 15 % the wetting time changed significantly. The wetting time for the top surfaces increased after stretching - to 97.42 s for the KF 1 fabric and to120 s for the KF 2 fabric. The wetting time for the bottom surface increased for the KF 1 fabric to 29.48 s whereas for the KS 2 fabric – decreased to 6.12 s. It is due to the fact that stretching caused the structure of both fabrics more loose with bigger open pores between threads. Thus, the testing solution was transferred from the top to the bottom surface easier and quicker due to the gravity.

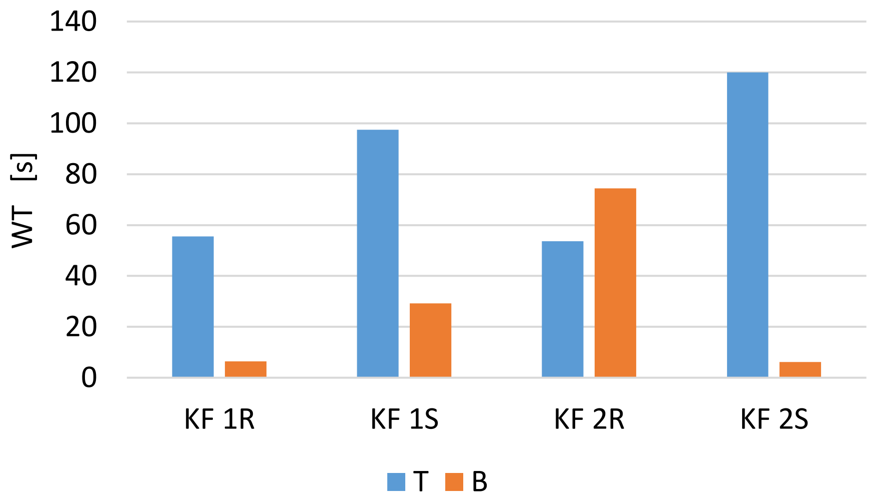


Fig. 7. Wetting time of the investigated samples: T – top surface, B – bottom surface, R – relaxed sample, S – stretched sample.

The results of the wetting time are in agreement with the results of the absorption rate (Fig. 8). The highest absorption rate was observed for the top surface of the samples in the flat state - 245.49 %/s for the KF1 fabrics, and 228.50 %/s for the KF 2 fabric. The absorption rate for the bottom surface of the relaxed samples is much lower than that for the top surface. It is 50.85 %/s for the KF 1 fabric, and 29.65 %/s for the KF 2 fabric. After stretching the absorption rate for the top surface decreased dramatically. For the KF 1 fabric it is 28.92 %/ s and 0 %/s for the KF 2 fabric. It is due to the fact that after stretching the open pores between threads of the fabrics increased and the testing solution was transferred very quickly to the bottom surface. In the same time the liquid on the top surface was absorbed in small amount and very slowly, and in the case of the KF 2 fabric the absorption in the top surface was not observed.

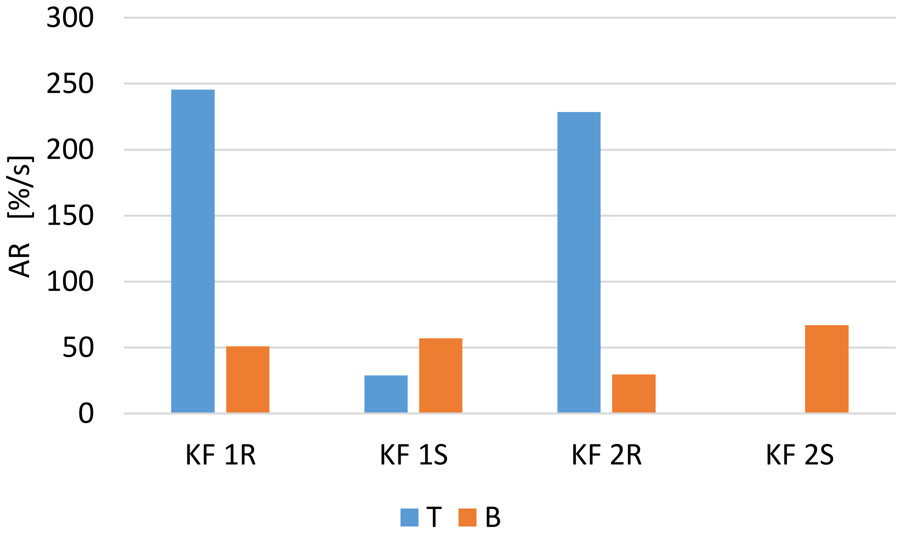


Fig. 8. Absorption rate of the investigated samples: T – top surface, B – bottom surface, R – relaxed sample, S – stretched sample.

In both cases the KF1 and the KF 2 fabrics the absorption rate for the bottom surface increased after stretching, and greater increase was observed for the KF 2 (rib stich) fabric. The spreading speed (Fig. 9) presents the opposite tendency to that observed for the wetting time.

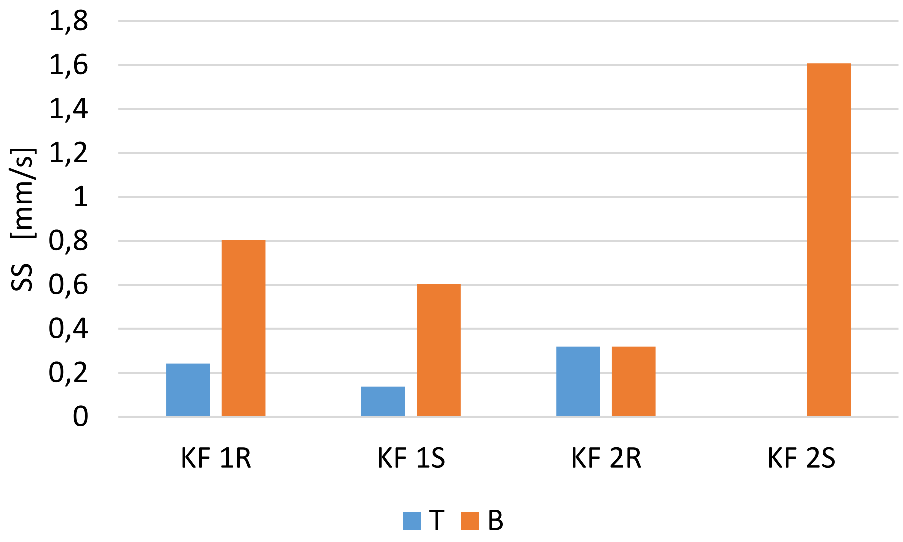


Fig. 9. Spreading speed of the investigated samples: T – top surface, B – bottom surface, R – relaxed sample, S – stretched sample.

The highest spreading speed is observed fort the bottom surface of the KF 2 fabric in the stretched state – it is 1.61 mm/s. Generally, the spreading speed for the bottom surface is significantly greater than that for the top surface with one exception: the KF 2 fabric in the relaxed state. In this case the spreading speed fort the top and bottom surface is the same – 0.32 mm/s. Probably, it results from the fact that both surfaces of the rib strict fabric are identical. However, the stretching causes the change of the relation between both surfaces of the KF 2 fabric in the aspect of the liquid spreading on them. In the case of the KF 1 fabric (single jersey) the direction of thread on both surfaces is different. It can be a reason of different liquid spreading on both surfaces.

Two last parameters: R - the accumulative one-way transport index, and the OMMC - Overall Moisture Management Capacity are the synthetic parameters calculated on the basis of the results for both surfaces according to appropriate algorithms built into the MMT software. Positive and high values of the R parameter show that liquid sweat can be transferred from the skin to the outer surface easily and quickly [31]. The value of the OMMC parameter can be in the range from 0 to 1. The higher value of the OMMC parameter is the better ability of fabrics to manage a liquid moisture. Results of the R and the OMMC (Tab. 2) show that the stretching by 15 % of stretch significantly improved the performance of both investigated fabrics. In the relaxed state the value of the R parameter for the KF 2 fabric is negative. It means that the fabric should be assess as poor in the aspect of transport of liquid moisture form the top to the bottom surface of the fabric. In the case of the KS 1 fabric in the relaxed state the value of the R parameter is high. It classifies the KF 1 fabric to the excellent grade [10] in the aspect of transfer of the liquid moisture form the top to the bottom surface. It is also observed that the improvement of the liquid moisture management capacity of the KF 2 fabric is much more significant than that of the KF 1 fabric. Comparison of the results for the relaxed samples show that the KF 1 fabric transfer the liquid moisture better than the KF 2 fabric. After stretching the relation is opposite.

4. Summing up

The cotton knitted fabrics of different structure have been measured in the range of their liquid transport properties. The measurement has been done for the fabrics in the relaxed state and stretched by the 15 % of stretch. The measurement has been performed by means of the Moisture Management Tester MMT M290. In order to stretch the fabrics the MMT Stretch Fabric Fixture device which is a supplementary device to the MMT. Applied method and instruments allow to assess the liquid moisture transport performance of the knitted fabrics in a complex way. Obtained results showed that the fabrics made of the same raw material but of different basic structural parameters differ between each other in the range of the parameters characterizing the liquid moisture transport. On the basis of the results we can state that stretching significantly improves an ability of the knitted fabrics to transfer the liquid moisture. However, improvement of liquid transport performance of the cotton knitted fabrics is also modified by the fabric structure.

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