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Static Water Absorption of Knits from Natural and Textured Yarns

Abstract
This study is a continuation of an experimental investigation to determine one of the comfort properties – static water absorption. The influence of knits from natural yarns and yarns plated with stretch thread on static water absorption is discussed. It was determined that higher water absorption is characteristic for knits from pure yarns, lower – for knits with textured polyamide thread, and the lowest - for knits with elastane thread. It was found that a higher tightness factor causes the worst water absorption. The variation of water absorption depending on the area density and thickness of plain and plated plain knits were discused.

Key words: *natural yarns, bamboo yarns, soybean yarns, cotton - seacell, bamboo - flax, air permeability, plated socks, linear density, area density, loop length, tightness factor.*

Introduction

Among the numerous studies concerning thermal comfort, besides sorption and water vapour penetration, experiments concerning the transport and sorption of liquid sweat are of considerable scientific significance. Moisture absorption includes the ability of a material to retain a liquid in its interstices and pores. Moisture flow through textile materials is important in a diverse range of textile applications, including casual wear, sportwear and protective wear, from a comfort point of view [1]. Moisture transmission through textile has a great influence on the thermo-physiological comfort of the human body, which is maintained by perspiring both in vapour and liquid forms.

Clothing can serve as a buffer in the moisture transfer process. The clothing to be worn should allow this perspiration to be transferred to the atmosphere in order to maintain the thermal balance of the body [2]. The performance of moisture absorption and its release depends primarily on the fiber properties. Most of the studies on this compare fibres types [2 - 7]. Natural fibers such as cotton, wool and flax are hydrophilic, meaning that their surface has bonding sites for water molecules. Therefore, such fibers have poor moisture transportation and release. Synthetic fibers such as polyester are hydrophobic, meaning that their surface has few bonding sites for water molecules. Hence, they tend not to get wet and have good moisture transportation and release [3 - 5]. During swelling, the fibre macromolecules or micro-fibrils are pushed apart by the water molecules absorbed, reducing the pore size between fibres and yarns, thus reducing water vapour transmission through the fabric. As the swelling increases, the capillaries between the fibres get blocked, resulting in lower wicking [2]. In a study conducted by Su et al., composite yarns were spun using profiled polyester fibers and cotton fibers at different blend ratios. Experiment results revealed that the duffusion rate and drying rate become better with a decreasing cotton content [7]. Wang et al. analysed moisture absorption and quick dry fabrics from profiled PES fibre [5]. Ozdil et al. investigated the effect of the yarn count and yarn twist coefficient of cotton yarns on the moisture properties of knitted fabrics. They noted that a higher twist coefficient value creates a compact structure, a maximum absorption rate, spreading speed and a decrease in the maximum wetted radius, whereas the wetting time of the fabrics increases[6]. Liquid sorption in two-layer packets of knitted materials was investigated by Bartkowiak and Szucht. They noted that viscose fibres are the most favourable of the traditional materials for sorptive layers. For diffusive layers, the best are non-hygroscopic fibres, especially textured polyester fibre [7].

Terry fabrics have a higher water absorption property compared to other types of textile fabrics, as the end uses of terry fabrics require this. Many researches have investigated the wetting phenomenon and water absorption of terry fabrics as it is the most popular for home textiles [8 - 12]. They all noted that the type of yarns used in the production of terry fabrics had the most significant effect on static water absorption properties. Warp and weft density, pile length, thickness, and area density are also significant characteristics. Besides this Baltakytė and Petrulytė investigated the wetting phenomenon and static water absorption of terry fabrics regarding the various impacts – water/heat/mechanical, as well as the finishing process – industrial washing [10, 11].

However, there is lack of studies about the water absorption of plain knits from natural yarns and plated knits with textured polyamide (PA) and elastane wrapped with textured polyamide thread (Lycra). The aim of this investigation was to determine what kind of yarns or its composite enables to obtain comfortable socks. While wearing such socks, we should feel comfortably dry. In a continuation of our previous works [13, 14], in this paper we have extended our study to research the other important comfort factor – water absorption.

Object and method of investigation

Materials

In the experiment the same samples were used as in our previous works [13, 14]: knits from 100% Cotton (C - 14 tex), 100% bamboo fibre produced from cellulose (man-made) (B - 14 tex), 100% soybean protein (S - 14 tex), and blended yarns: 75% Cotton - 25% seacell (CS - 19 tex), 80% bamboo - 20% flax (BF - 24 tex) and knits plated with textured polyamide (20 tex) or elastane (2.2 tex) thread wrapped with textured polyamide (7.8 tex) were investigated. The static water absorption of the samples investigated are presented in ***Figure 1***.

Method

The static water absorption was measured according to method [8]. The samples were conditioned in laboratory conditions, cut into pieces (10 × 10) and weighed, m_d. After that the samples were kept for one minute in distilled water. After being removed from the water, they were hung for three minutes to remove excess water, and the weight of the wet samples m_W was measured. The static water absorption S_W in % was calculated using the following formula:

$$S_w = \frac{m_w - m_d}{m_d} \times 100\,\% \qquad (1)$$

The thickness of the knitted samples *b* was measured accordance to ISO 5084:1996 [15].

Experimental results

In this work the static water absorption of socks manufactured from various yarns, such as pure, blended and a combination with textured polyamide or elastane thread was investigated. The measurements were repeated 3 times, the average values of which are presented in ***Figures 1, 2*** & ***3***. Relative error values of static water absorption were calculated, and it was found that the error did not exceed 5%, with only two variants of cotton/seacell not exceeding 8%.

Regarding static water absorption, the range of values obtained is significant, ranging from 308.43 – 641.49%. As is seen in ***Figure 1***, knits from pure yarns have the highest values. Lower values are shown by knits manufactured from a composition with elastane and textured polyamide thread.

Influence of natural fibre knits on static water absorption

As in our previous works [13, 14], six groups of knits were used with the same linear density of yarns. The first group of knits is (XE – SE, CE, BE) from 24 tex yarns, the second (XX – SS, CC, BB) from 28 tex yarns, the third (XPA – SPA, CPA, BPA) – 34 tex yarns, the fourth (XXE – SSE, CCE, BBE) – 38 tex yarns, the fifth (XXX – SSS, CCC, BBB) – 42 tex yarns, and the sixth (XXPA – SSPA, CCPA, BBPA) – 48 tex yarns.

From ***Figure 2*** we can see that samples from the second and fifth groups (knits from pure yarns) have higher static water absorption than the other groups, except pure cotton samples (CC, CCC), where there is a converse variant. Although the thickness and area density of the first (XE), third (XPA), fourth (XXE) and sixth (XXPA) groups are higher than those of the second (XX) and fifth (XXX) groups, the knits have about 20% lower static water absorption. Wang et al. wrote that a higher tightness factor results in worse water absorption [5]; we can con-

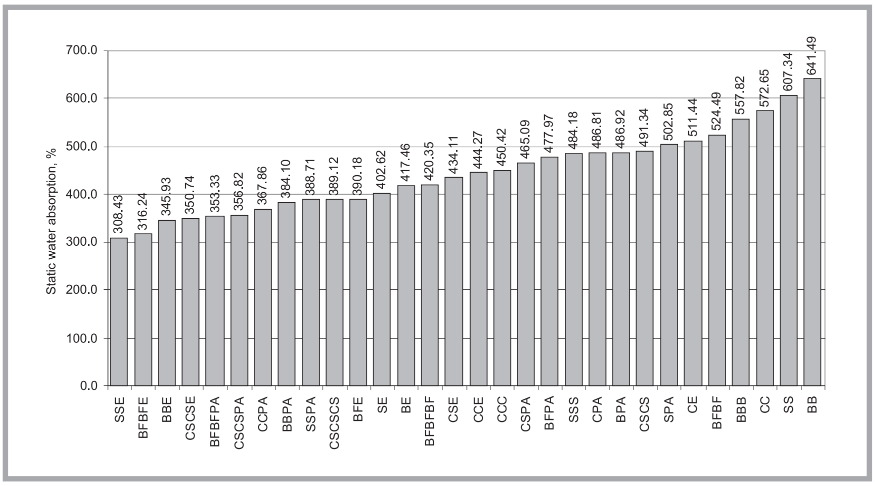

Figure 1. *Static water absorption of knitted socks samples.*

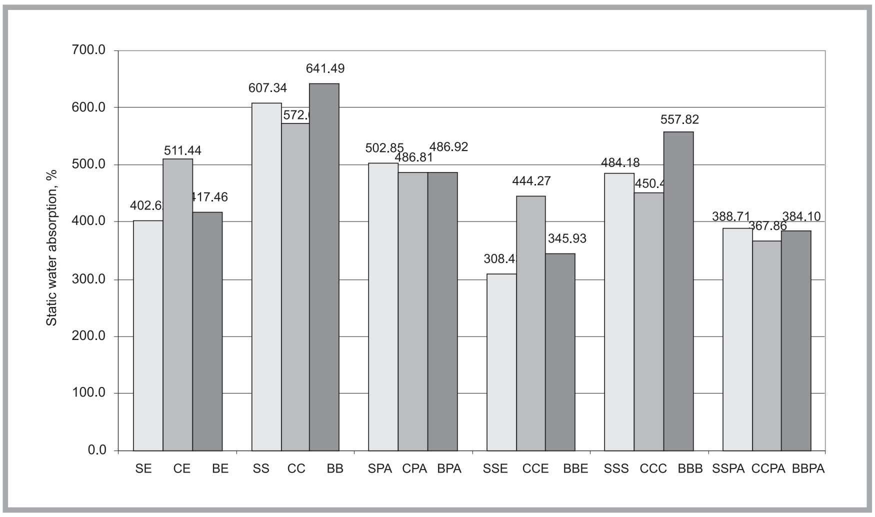

Figure 2. *Static water absorption of pure knits manufactured from soy, cotton, bamboo (linear density XX-28 tex, XXX-42 tex) and its combination with elastane (XE-24 tex, XXE-38 tex) and textured polyamide (XPA-34tex, XXPA-48 tex) threads.*

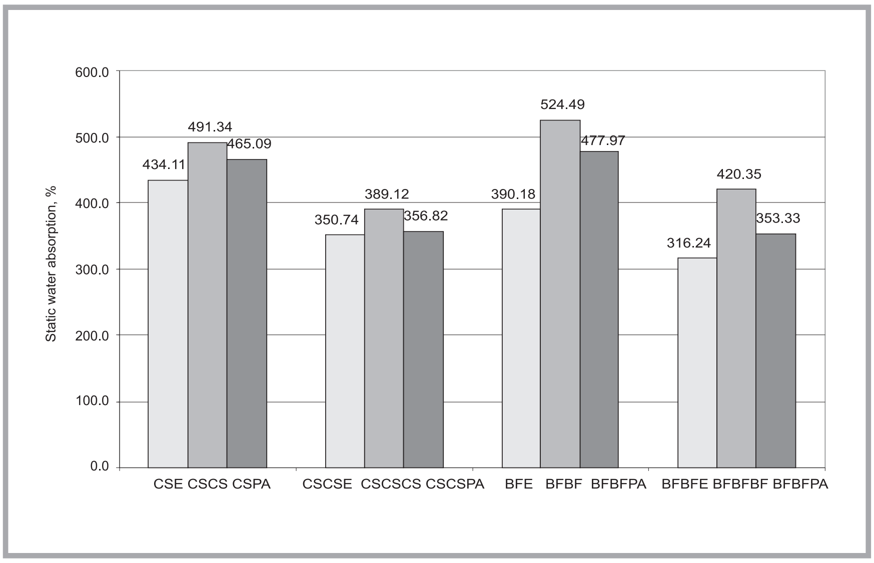

Figure 3. *Static water absorption of knits manufactured from Cotton – seacell (CSCS-38 tex, CSCSCS-57 tex), comabination with elastane (CSE-29 tex, CSCSE-48 tex) and textured polyamide (CSPA-39 tex, CSCSPA-58tex); Bamboo – flax (BFBF-48 tex, BFBFBF-72 tex), combination with elastane (BFE-34 tex, BFBFE-58 tex) and textured polyamide (BFPA-44 tex, BFBFPA-68 tex) threads.*

firm this proposition because it is obvious that the third (XPA), fourth (XXE) and sixth (XXPA) groups have the highest tightness factors of all the knit variants. An explanation could be that these types of stretch thread (polyamide and elastane) do not get wetted and, hence, could be used as a good moisture transporter. All the knitted structures have synthetic fibre near the skin, because of which the human will feel comfortably dry. Comparing the raw materials, we can see that cotton samples behave differently from those of bamboo and soy. In the second (XX) and fifth (XXX) groups, cotton knits have lower water absorption, about 8% and 14% respectively, than those from bamboo and soy, but in the first (XE) and fourth (XXE) groups, cotton knits have about 25% and 36% higher water absorption than bamboo and soy knits, respectively. The water absorption of knits of the third (XPA) and sixth (XXPA) groups are similar.

One more tendency is obvious in ***Figure 2***. The static water absorption of all knits plated with textured polyamide thread (third and sixth groups) have almost the same values. An explanation could be that polyamide thread (in a structure of pure yarns and yarns plated with PA thread) comprises more than 50% of all the linear density; such a structure differs from those of other samples from pure thread and thread plated with elastane. Such stretch yarns comprise most of the structure properties and absorb as well as release a higher amount of water, while pure yarns such as cotton, bamboo and soy do not play a very significant part in absorbing water in this structure.

Comparing knits manufactured from two and three yarns (***Figure 2***), we can see that static water absorption is higher in knits from two yarns, about 17%, 18% and 23%, respectively, for those plated with elastane, pure knits, and those plated with textured polyamide, manufactured from three yarns.

Figure 3 presents the results of samples from blended cotton - seacell and bamboo - flax yarns and a combination with elastane and polyamide. Comparing the water absorption of knits manufactured from pure cotton - seacell and bamboo - flax yarns, we can see that they behave similar to variants from cotton or bamboo yarns: higher water absorption is characteristic for knits from pure yarns,

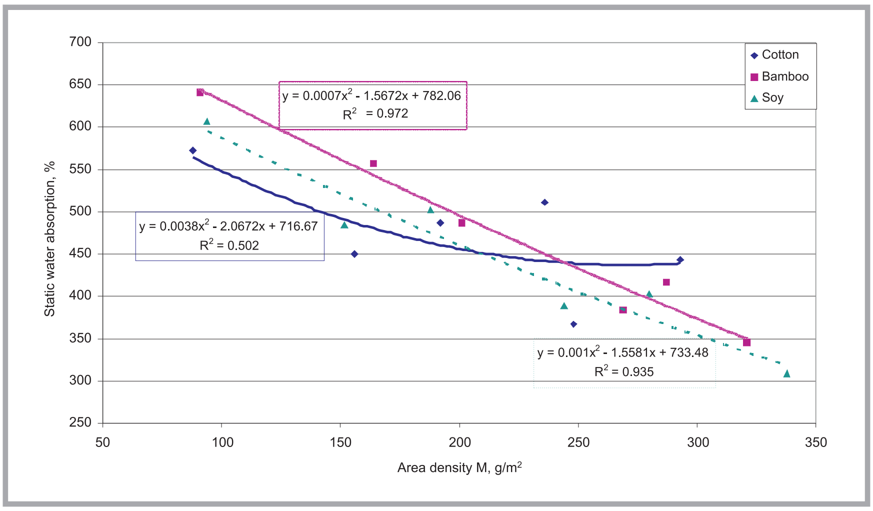

Figure 4. *Static water absorption as the function of area density of all cotton (♦), bamboo (■), soy (▲) knits variants.*

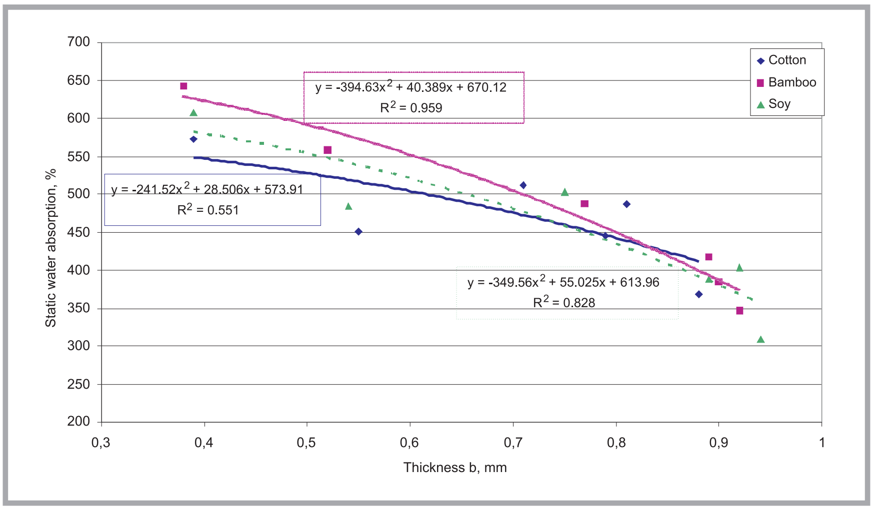

Figure 5. *Static water absorption as the function of thickness of all cotton (♦), bamboo (■), soy (▲) knits variants.*

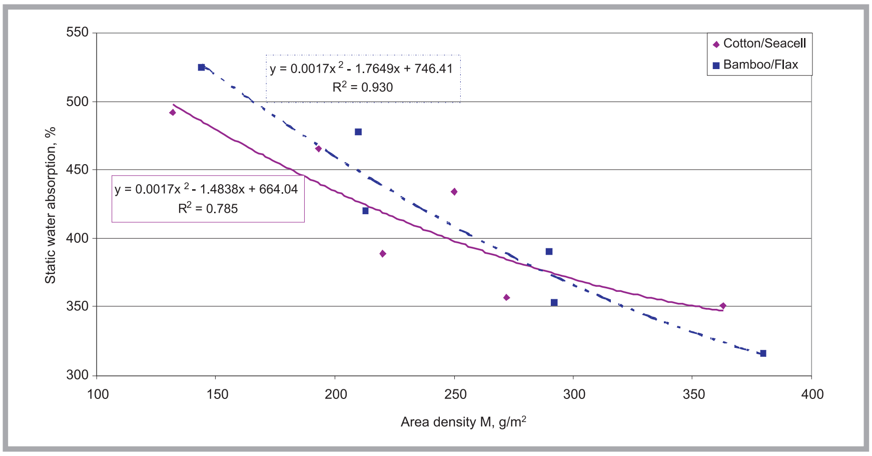

Figure 6. *Static water absorption as the function of area density of all cotton/seacell (♦), bambo/flax (■), knits variants.*

and lower for knits with a combination of polyamide and elastane thread. As in previous figures, knits with a higher area density have lower water absorption.

The same tendency of the higher water absorption of two yarns, as in ***Figure 2***, we can notice in ***Figure 3***. The absorption of two yarns is about 19%, 21% and

26% higher, respectively, for knits from cotton – seacell and bamboo – flax plated with elastane, as well as for knits from pure cotton and those plated with textured polyamide.

To describe the results of the dependence of water absorption on area density and thickness, a polynomial equation was used, because it shows the highest determination coefficient. To obtain this dependence, all the plain and plated knits for each fibre were used. ***Figure 4*** presents the dependence of water absorption on the area density of knits from cotton, bamboo and soy, as well as the determination coefficient of the equation obtained: $R^2 = 0.502$ (cotton), $R^2 = 0.972$ (bamboo), $R^2 = 0.935$ (soy). As can be seen from the results, there is strong dependence of knits from bamboo and soy fibres, whereas for cotton knits it is very low, and there is no dependence between static water absorption and area density. The same tendency is with the dependence of water absorption on the thickness of knits from cotton, bamboo and soy, as in ***Figure 5***: the determination coefficient of the equation is $R^2 = 0.551$ (cotton), $R^2 = 0.959$ (bamboo), $R^2 = 0.828$ (soy). As is mentioned above, it is evident that the determination coefficient of the cotton variant is too low to be compared with the other two fibres. Although there are no dependences, the tendency of the curvature is almost the same as that for bamboo or soy knits. Such low dependences of cotton knits could be because of their tighter structure; besides, compared with bamboo and soy knits, cotton knits have a rougher surface. In ***Figure 6*** we can see the dependence of water absorption on the area density of knits from cotton/seacell and bamboo/flax. Knits from cotton/seacell fibre have a little bit lower determination coefficient, $R^2 = 0.785$, than bamboo/flax - $R^2 = 0.930$, which could be explained by the fact that cotton fibre also has an influence on this dependence, but in this study cotton was blended with another fibre, hence we can state that even a little amount of another fibre will increase water absorption.

Verification of the correlation between the static water absorption of samples from pure yarns, their combination with Lycra and textured polyamide thread and the tightness factor *TF*, area density *M* and thickness *b* was performed. There is a negative correlation between the water absorption and tightness factor (r = -0.91), area density (r = -0.98) and thickness (r = -0.96) of knits from pure yarns of the second group. The correlation between the water absorption and tightness factor of the sixth (XXPA) group was r = -0.88. A negative correlation between the water absorption and thickness of the third (XPA) group was r = -0.93. We can state that this is because of textured polyamide thread in the third and sixth groups, where absorption values are almost equal. The correlation between the water absorption and area density of the first group was r = -0.89. The other knit variants have low correlation values, not exceeding r = 0.80.

Conclusions

The research on the static water absorption of cotton, bamboo, soybean, cotton - seacell, and bamboo - flax knitted socks of different stucture parameters and raw material composition can be summarised as follows:

- It was determined that higher static water absorption is characteristic for knits manufactured from pure yarns only, lower – for knits with textured polyamide, and the lowest – for knits with elastane thread. Unwetted stretch thread (polyamide and elastane) could be used as a good moisture transporter. Water stays in a pure knit structure and does not dry so fast as knits plated with elastane and polyamide thread. Because of this feature, the knits would not be comfortable for socks, because the human would feel an unpleasant wetness and cold.

- Comparing knits manufactured from two and three yarns (***Figure 2***), we can observe that static water absorption is higher for knits from two yarns, about 17%, 18% and 23%, respectively, for knits plated with elastane, pure knits, and those plated with textured polyamide than knits from three yarns. The water absorption of knits from bamboo yarns is higher than those from soy yarns.

- Static water absorption decreases with an increase in the area density and thickness of the samples; therefore these parameters and water absorption have a good correlation for different kinds of bamboo and soy fibre. The experimental results are best described by the polynomial equation for the function of water absorption to area density: the determination coefficients of the equations obtained are $R^2 = 0.972$ (bamboo) and $R^2 = 0.935$ (soy). The determination coefficient for the function of water absorption to thickness is $R^2 = 0.959$ (bamboo) and $R^2 = 0.828$ (soy). Cotton knits are characterised by a very low determination coefficient, and there is no dependence between these two factors; on the other hand the tendency of curvature is the same as for bamboo or soy knits. Knits from cotton/seacell fibre have a little bit lower determination coefficient, $R^2 = 0.785$, than bamboo/flax $R^2 = 0.930$.

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Received 15.12.2009 Reviewed 25.11.2010