Comfort-related properties of the seersucker woven fabrics

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Abstract. Clothing creates a barrier between the human body and surroundings. Dependably on the predestination, it protects the human organism against outer factors dangerous for human health and safety. From the point of view of human health and well-being, the comfort-related properties of clothing are very important. The aim of presented work is to investigate the seersucker woven fabrics in the range of their comfort-related properties and to analyse an influence of the structure of fabrics on their properties. 9 variants of the seersucker woven fabrics were the objects of the investigation. The fabrics were manufactured from cotton yarns. In the experimental fabrics, 3 kinds of repeat of the seersucker pattern and 3 kinds of weft yarns were applied. Measurements of the comfort-related properties of the investigated fabrics have been performed using the following testing devices: Alambeta, Permetest and Moisture Management Tester. Results showed that both structural factors of fabrics: repeat of the seersucker effect and a kind of weft yarn influence the thermal insulation properties of the fabrics being investigated. Especially, the repeat of the seersucker effect influences the thermal conductivity, thermal absorptivity and thermal resistance in the statistically significant way at the probability level p = 0.05.

1. Introduction
Protection of human being is primal and one of the most important functions of clothing. Clothing creates a barrier between the human body and surroundings. Dependably on the predestination, it protects the human organism against outer factors dangerous for human health and safety. From the point of view of human health and well-being, the comfort related properties of clothing are very important. There are many factors influencing an ability of clothing to ensure the thermo-physiological comfort of clothing usage. An appropriate selection of textile materials from the point of view of their comfort-related properties plays a significant role in ensuring the thermal comfort. Thermal resistance, moisture transport and air permeability are considered as the most important comfort-related properties of textile materials [1].

Some researchers [2, 3] consider that the seersucker fabrics have good comfort properties. It results from their puckered structure. A typical seersucker structure is characterized by occurring the puckered strips in warp direction (figure 1). The seersucker fabrics are considered as the three-dimensional (3D) fabrics. Such structure is usually received on loom by an application of two warps of different tension [3].
Figure 1. Example of seersucker woven Fabric.

Figure 2. Schematic diagram of air circulation between the seersucker woven fabric and human skin.

The puckered effect generates air spaces between body and fabric. It ensures cooling of the user’s body in hot conditions, because the puckered area of the seersucker fabric holds the fabric away from the skin (figure 2). It facilitates the circulation of air and water-vapor.

Matusiak and Fraceczak [4] showed up that the seersucker woven fabrics are characterized by low values of the thermal absorptivity in a wet state. According to Hes et al. [5, 6], it provides an excellent physiological comfort conditions while using the clothing made of such kind of fabrics.

The aim of the presented work is to investigate the seersucker woven fabrics in the range of their comfort-related properties and to analyse an influence of the structure of fabrics on their properties.

2. Materials and methods

Totally, 9 variants of the seersucker woven fabrics were the objects of the investigation. The fabrics were manufactured from cotton yarns. In the experimental fabrics, 3 kinds of repeat of the seersucker pattern and 3 kinds of the weft yarns were applied. Both warps: basic and puckering were made from the same yarn: 20 tex x 2 cotton. As a weft the following yarns were used: 20 tex x 2, 25 tex x 2 and 30 tex x 2.

The following variants of pattern of the seersucker effect were applied (figure 3):

- variant MM1 – width of puckered and flat strips appropriately: 4 mm and 8 mm,
- variant MM2 – width of puckered and flat strips appropriately: 9 mm and 17 mm,
- variant MM3 – width of puckered and flat strips appropriately: 10 mm and 37 mm.

The fabrics were finished by a tensionless method. The finishing process included washing, rinsing and drying. Because the fabrics were manufactured from 2 ply yarns, the warps did not have to be sized. Due to this fact, the desizing process was unnecessary. The fabrics being investigated were measured in the range of their basic structural parameters. The results are presented in table 1.

Figure 3. Pictures of the seersucker woven fabrics being investigated: a) variant MM1, b) variant MM2, c) variant MM3.
Table 1. The basic structural parameters of the seersucker woven fabrics being investigated.

| Variant of repeat of the seersucker effect | Weft yarn | Mass per square meter g/m² | Warp density threads/dm | Weft density threads/dm |
|-------------------------------------------|-----------|-----------------------------|-------------------------|------------------------|
| MM1 20 tex x 2                            | 221.88    | 137.6                       | 120.2                   |
| MM1 25 tex x 2                            | 253.03    | 134.6                       | 116.0                   |
| MM1 30 tex x 2                            | 262.62    | 137.8                       | 108.0                   |
| MM1 20 tex x 2                            | 216.96    | 136.8                       | 118.0                   |
| MM1 25 tex x 2                            | 236.76    | 138.0                       | 109.6                   |
| MM1 30 tex x 2                            | 254.75    | 134.0                       | 105.6                   |
| MM2 20 tex x 2                            | 205.43    | 127.8                       | 116.8                   |
| MM2 25 tex x 2                            | 227.06    | 129.8                       | 111.6                   |
| MM2 30 tex x 2                            | 243.50    | 131.0                       | 104.6                   |

Measurements of the comfort-related properties of the investigated fabrics have been performed using the following testing devices: Alambeta, Permetest and Moisture Management Tester M290 (MMT). The Alambeta is a computer-controlled instrument for measuring the basic static and dynamic thermal characteristics of textiles [4, 5, 7, 8]. This method belongs to the so called “plate methods”. The principle of measurement by means of the Alambeta relies on the convection of heat emitted by the hot upper plate in one direction through the measured sample to the cold bottom plate. It is a two-plate measuring device developed by Hes (Sensora, Czech Republic). The Alambeta measures: thermal conductivity, thermal diffusivity, absorptivity, thermal resistance and fabric thickness. For each fabric variant 10 repetitions were performed. Measurement was done in the standard climatic conditions.

The Permetest was also developed by Hes (Sensora, Czech Republic). This device can be considered as a portable “skin model”. By means of the Permetest, the following comfort-related properties are determined: thermal resistance, water-vapor resistance and relative water-vapor permeability [1]. By means of the Permetest, 3 repetitions of measurement were performed for each fabric variant being investigated.

The Moisture Management Tester (SDL Atlas) is an instrument designed to measure the dynamic liquid transport properties of textiles such as knitted and woven fabrics in three aspects [9]:

- 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.

The device is controlled by a PC and MMT290 SOFTWARE. Measurement is performed for samples cut into 80 mm x 80 mm squares. For each fabric 5 repetitions of measurement are performed. 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 [10]:

- spreading outward on the upper surface of the fabric,
- transferring through the fabric from the upper surface to the bottom surface,
- spreading outward on the bottom surface of the fabric.

In order to assess a statistical significance of the influence of structural parameters of the seersucker woven fabrics on their comfort-related properties, a statistical analysis of the results was performed using the multifactor ANOVA available in STATISTICA software. The repeat of the seersucker effect and a kind of weft yarn were taken as the independent variables (main factors), whereas the comfort related properties were the dependent variables. Statistical significance was assessed at the significance level 0.05.

3. Results and discussion
Results of measurement using the Almbeta, Permetest and Moisture Management Tester showed that both structural factors of fabrics; repeat of the seersucker effect and a kind of weft yarn, influence the thermal insulation properties of the fabrics being investigated.

3.1. Results from the Alambeta

Statistical analysis using the ANOVA shows that the repeat of the seersucker effect and a kind of weft yarn influence the thermal conductivity, thermal absorptivity and thermal resistance of the fabrics in statistically significant way at the 0.05 significance level. The highest thermal conductivity was stated for the fabrics representing the MM3 variant of the seersucker effect repeat (figure 4). However, it is statistically observed a significant interaction between two main factors: seersucker effect repeat and a kind of weft yarn. Influence of the repeat of the seersucker effect on the thermal conductivity is modified by a kind of weft yarn (figure 5). In the case of fabrics containing the 25 tex x 2 and 30 tex x 2 weft yarns the lowest thermal conductivity was stated for the fabric representing the MM2 pattern variant.

![Figure 4](image1.png)  ![Figure 5](image2.png)

**Figure 4.** Thermal conductivity of the seersucker woven fabrics of different repeat of the seersucker effect.

**Figure 5.** Thermal conductivity of the seersucker woven fabrics in function of repeat of the seersucker effect and a kind of weft yarn.

![Figure 6](image3.png)  ![Figure 7](image4.png)

**Figure 6.** Thermal resistance of the seersucker woven fabrics in function of repeat of the seersucker effect and a kind of weft yarn.

**Figure 7.** Thermal absorptivity of the seersucker woven fabrics of different repeat of the seersucker effect.
In the case of the thermal resistance and thermal absorptivity it was also stated that the influence of the seersucker effect pattern and a kind of weft yarn as well as the interaction between both independent variables (main factors) are statistically significant at the significance level 0.05. However, thermal resistance of the seersucker fabrics is decreasing from the MM1 to the MM3 variant of pattern (figure 6), whereas for the thermal absorptivity the tendency is opposite (figure 7). The thermal absorptivity is the surface property. It expresses the warm/cool feeling while first contact of fabric with human skin. In the case of the MM3 variant the share of the puckered strips in total area of fabrics is the lowest in comparison to the MM1 and MM2 fabric variants. It means that in the case of the MM3 fabric variant the number of direct contact points between the fabric and human skin is the lowest. It influences the heat absorption by the fabric.

3.2. Results from the Permetest

The results from the Permetest confirmed the relationships between the thermal resistance and structure parameters of the investigated fabrics. The thermal resistance decreases from the MM1 variant to the MM3 variant (figure 8). However, it should be mentioned here that in the measuring channel of the Permetest, it is an air movement of the velocity 1.0 m/s. The puckered strips can disturb the air movement. The question was how should the samples of the seersucker woven fabrics be placed on the measuring channel of the device: puckered strips parallel or perpendicular to the direction of air movement? Performed investigations showed that the thermal resistance measured by means of Permetest at parallel to the air movement placement of puckered stripes is lower than that measured at perpendicular placement (figure 9) and the difference between them is statistically significant. It should be taken into consideration while assessing such kind of patterned fabrics by means of the Permetest.

3.3 Results from the Moisture Management Tester

The Moisture Management Tester provides 10 different parameters characterizing the fabrics from the point of view of their ability to transport of the liquid moisture. It is impossible to present all of them in this paper. Due to this fact, the detailed results from the MMT will be the presented in separate publication. Generally, the results showed that the seersucker fabrics being investigated should be classified as fast absorbing and slow drying fabrics. The average values of the Overall Moisture Management Capacity (OMMC) was not higher than 0.4. It is a medium level because the range of this parameters is from 0 to 1. The higher value of the OMMC parameter is the better ability of fabric to transport the liquid moisture. It was also observed that in the majority of cases the pattern of the seersucker effect influences the values of parameters assessed by the MMT.
Obtained results allowed drawing two important conclusions from the point of view of the assessment of such kind of patterned fabrics as the seersucker woven fabrics in the range of their moisture transport capability. First of all, it was stated that the puckered strips disturb the spreading of liquid moisture in the warp direction of the fabric. Secondly, while measuring the seersucker woven fabrics by means of the MMT the placement of sample is very important. During the test a pre-defined amount of test solution (synthetic sweat) is introduced onto the upper side of the fabric in one, central point, and then the test solution is transferred onto the material in three directions. Depending on whether the droplets fall on a flat or puckered area of the sample, a moisture spreads in different ways. In the presented investigations, the placement of samples was done in such a way that the synthetic sweat droplets were falling on the puckered surface. It is due to the fact that while using the clothing made of the seersucker woven fabrics, the puckered area of the fabrics adheres to the user's skin and absorbs sweat from the skin.

4. Conclusions
Performed investigations confirmed that the structure of the seersucker woven fabrics significantly influences the majority of comfort-related properties of the fabrics. The repeat of the seersucker effect influences the thermal conductivity, thermal resistance, thermal absorptivity as well as the moisture transport ability. In some cases, there is also statistically significant interaction between the main structural factors: repeat of the seersucker effect and a kind of weft yarn. In the case of measurement by means of the Permetest, the placement of the sample in measurement channel is also important for the results of thermal resistance measurement. The values of thermal resistance determined when the direction of the puckered strips is parallel to the air movement are lower than that determined when the direction of the puckered strips is perpendicular to the air movement.

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