THERMOFISIOLOŠKE KARAKTERISTIKE PLETENINA ZA IZRADU SPORTSKOG VEŠA

INTRODUCTION

Sports underwear should meet the needs of modern athletes. It should provide maximum comfort to the wearer during certain activities, so the choice of materials for its production is of special importance. For this purpose the latest achievements are used in the field of fibers performance, textile surfaces and manufacturing technology, /1-6/. The main advantage of sportswear made of textile materials of special properties is the simultaneous controlling of heat and humidity and breathability (ventilation). Humidity control involves regulating body temperature and preventing increase garment weight from sweating, /7/. In the sports underwear production there are also used combinations of materials with different properties in order to apply the right material for each zone of the human body. The used materials allow the heating and cooling of different body parts at different rates, which ensures optimal body climate. This paper examines the properties of four knitwear made of different materials and different interlacement, which are use for making sports underwear. They proposed their application for certain climatic conditions and levels of activity. In this paper the level 1 system is applied for the analysis of physiological properties of textiles and garments for comparing different characteristics of textile materials used in the manufacture of sports clothing, /8/.

Abstract

In this paper are examined and compared properties of four knitted fabrics for making sports underwear: knitwear of 100% polyester and mixture of polyester/cotton and cotton/elastane. The aim is choosing appropriate knitwear for making sports underwear, considering various climate conditions and consumer activity. The results show that the thermal-, water vapour- and air permeability properties, that affect the comfort of garment, depend on the type fiber used and structural parameters of knitwear. Knitwear in interlock pique interlacement of polyester and cotton mixture has properties suitable for warmer climates and moderate activities, whereas the knitwear of polyester in jacquard interlacement with the trap on each loop is suitable for intense activities in a warm climate, but for materials which are not in contact with the skin. Knitted polyester in jacquard interlacement with the trap on the second loop, according to its properties, is suitable for application in cold conditions, whereas the interlock knitwear raising on one side of mixture of cotton and elastane is not recommended for production of sports underwear. The results are important for the selection of appropriate knitted fabrics or their combinations in sports underwear manufacture to satisfy certain requirements of thermophysiological comfort.

Keywords

• knitted fabrics
• sports underwear
• activewear
• thermophysiological properties
• heat and moisture management

Izvod

U radu su ispitivana i poređena svojstva četiri pletenine za izradu sportskog veša: pletenine od 100% poliestra i mešavine poliestra/pamuk i pamuk/elastan. Cilj rada bio je da se za izradu sportskog veša odabere adekvatna pletenina, imajući u vidu različite klimatske uslove i nivoe aktivnosti nosilaca. Rezultati su pokazali da termo-fiziološka udobnost, termofiziološka odolnost i upravljanje topotom i vlagom su na primenu za izradu sportskog veša.
EXPERIMENTAL PART

The experimental part is conducted at the CIS Institute (Belgrade, Serbia). Properties of four knitted fabrics (marked as samples 1-4) are examined and compared with different compositions and types of interlacement for sports underwear production, which are shown in Table 1.

Table 1. Examined textile materials (magnification 4×).

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<tbody>
<tr>
<td>1</td>
<td>100% PES</td>
<td>Jacquard</td>
<td>0.7</td>
<td>134.4</td>
<td>0</td>
<td>444.7</td>
<td>4</td>
<td>1063.9</td>
<td>Fimt = 0.003</td>
<td>4907.1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2</td>
<td>92% PES, 8% Co</td>
<td>Interlock pique</td>
<td>0.44</td>
<td>135.6</td>
<td>626</td>
<td>435.2</td>
<td>2</td>
<td>1099.4</td>
<td>Fimt = 0.03</td>
<td>4088.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>91.5% Co, 8.5% El</td>
<td>Interlock twitched on one side</td>
<td>0.81</td>
<td>193.1</td>
<td>452.5</td>
<td>2</td>
<td>4</td>
<td>152.8</td>
<td>Fimt = 0.05</td>
<td>3979.98</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>100% PES</td>
<td>Jacquard (trap on each loop)</td>
<td>0.54</td>
<td>123.8</td>
<td>329.5</td>
<td>3</td>
<td>4</td>
<td>862.83</td>
<td>Fimt = 0.07</td>
<td>4432.3</td>
<td>0</td>
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The tests includes the determination of:
- the composition of 4 knitted fabrics and linear density of the yarn from which they are made of,
- types of interlacement, thickness and mass per unit area of knitted fabrics,
- thermophysiological properties of knitted fabrics: air permeability, water vapour transmission, water repellency, waterproof-hydrostatic pressure test, resistance to water vapour (Ret) and thermal resistance (Rct),
- dimensional change after washing at 40°C (shrinkage).

Applied methods for determining physical and thermophysical properties of the tested materials are listed in Table 2 with the corresponding test property. For determining specific thermal properties of clothing there are tests in which the heated flat plates are used, /8, 10, 11/. At that, the quantity of water vapour absorbed by the sample of the material during one hour exposure on the skin model (standard wet flat plate) /8, 10, 11/ represents a measure of moisture transfer and is denoted by $F_i$ (%), and it depends on material thickness.

In order to allow comparison between textile materials, a water vapour permeability index, $I_{wat}$, is used which compares the thermal resistance ratio ($R_{ct}$) with resistance to water vapour ($R_{wv}$) of the textile material, whose values range between 0 (impermeable material) and 1. $F_i$ and $I_{wat}$ are used to assess the physiological quality of textile material (high $I_{wat}$ and $F_i$ values are desirable), /8, 12/.

RESULTS AND DISCUSSION

Results of testing certain properties of four knitted fabrics are shown in Table 2. Sample 1 represents a 100% PES jacquard knitted fabric with a trap on another loop; sample 2 is a knitted fabric made of 92% PES and 8% cotton mixture in interlock pique interlacement; sample 3 is a interlock knitted fabric raising on one side, made of 91.5% cotton and 8.5% elastane mixture; and sample 4 is a 100% PES jacquard knitted fabric with a trap on each loop.

In order to be able to select appropriate materials for making sportswear for certain climatic conditions and levels of activity, their properties are compared. The thickness of the knitted fabric and mass per unit area depend on...
from steam density, so as is expected, sample 3 has the highest thickness and mass per unit area, considering the type of interlacement and linear density of the yarn, i.e. linear density of the yarn, interlacement, and that it was raising on one side. According to the thickness, follow samples 1 and 4, and the smallest thickness has sample 2. The mass per unit area of these samples does not follow the thickness of the knitted fabric due to different voluminous, i.e. stitch densities, which is a result of various interlacement, so that samples 1 and 2 have approximately the same mass per unit area, from which the mass per unit area of the sample 4 slightly deviates (Fig. 1).

The largest puncture force has knitted fabric (sample 2) with interlacement interlock pique (Fig. 2). The weakest puncture forces are obtained on sample 4, where the interlacement is jacquard (trap on every loop). Interlacement interlock-pique has the largest number of stitches per unit area which affects the high results of puncturing forces. Based on Fig. 3, it is concluded that during the procedure peeling process the largest changes occur on sample 3. The visual effect of the knitted fabrics after the peeling process on the sample 3 is rated by grade 2, which is very bad. The ripping process has contributed in breaking the twisted fibers in the yarn, and afterwards the short fibers have propensity surface fuzzing on the knitted fabric. These fibers in the process of peeling have formed into pills. Samples 1 and 4 have a jacquard interlacement, and on the peeling process is a grading of 4. The best grade is on sample 2 which was produced in the interlock-pique interlacement.

The highest air permeability (Fig. 4) show samples 2 and 1, and the smallest on sample 3, which indicates a significant impact on the structure, thickness and number of stitch density, the air permeability, as well as fiber geometry. The lowest air permeability shows the thickest knitted with the highest mass per unit area and the highest stitch density (interlock raising on one side).

A larger surface of the fibers and thicker knitwear of sample 1 cause lower air permeability than in the sample 2, whereas the stitch density and structure of sample 4 probably cause less air permeability compared to samples 1 and 2. Sample 1 shows the highest water vapour transmission, Fig. 4, which is correlated with the fiber morphology and hydrophobicity of PES fibers. Slightly lower water vapour transmission of sample 4 is a consequence of knitwear characteristics: structure, thickness, and number of stitches. Sample 3 shows the lowest water vapour transmission which is in accordance with its thickness, mass per unit area and interlacing, as well as material composition - a high percentage of cotton, which swells due to the moisture absorption.
knitted fabrics are within the tolerance boundaries. Fabrics, where allowed shrinkage is up to 5%, all of the same. Considering the fact that we are discussing knitted ances, both in width and length (Fig. 6), which is in accord-
est content of cotton shows the greatest changes in dimen-
sions when washing, while the sample with the high-
wear. Samples 1 and 4 (100% PES) show no change in
knitted fabric 2 is characterized as acceptable for a warm
climate in all layers, especially for medium activity;
knitted fabric 3 is not recommended for use in sportswear;
knitted fabric 4 can be applied in a warm climate as an
intermediate or outer layer for intensive activities.

Further implications are that knitted fabric 1 is acceptable
for making sportswear for cold weather applications, and
knitted fabric 2 for use in a warm climate, while knitted
fabrics 3 and 4 are not recommended for making sports-
ware. Samples 1 and 4 (100% PES) show no change in
dimensions when washing, while the sample with the high-
est content of cotton shows the greatest changes in dimen-
sions, both in width and length (Fig. 6), which is in accordance
with the nature of the raw materials that they are made of. Considering the fact that we are discussing knitted fabrics, where allowed shrinkage is up to 5%, all of the knitted fabrics are within the tolerance boundaries.

Moisture transfer properties (amount of water vapour absorbed by a sample of material during one-hour exposure on the skin model) of samples examined could not be compared due to different thicknesses of samples, so the index \( \text{Imt} \) is applied for comparing the physiological quality. Sample 1 shows the best physiological quality (Fig. 7), as a consequence of fiber morphology, and sample 3 shows the weakest physiological quality, as a consequence of knit-
wear characteristics.

CONCLUSIONS

The results show that thermal and moisture management performances of examined knitwear largely depend on the properties of raw materials they are made of, the characteristics of knitwear and structures, especially the thermal properties and the air and water vapour transmission.

It can be concluded that samples 2 and 4 are suitable for warmer climates, because they show lower thermal resistance (higher thermal conductivity) and higher water vapour permeability, while sample 2 shows higher absorptivity too, given the nature of the components it is made of. At the same time, sample 2 is more suitable for medium-activities, and sample 4 for intensive activities, since they exhibit a high air permeability and low heat resistance, and sample 4 is of high water vapour permeability too (high water vapour transfer). Sample 1 is suitable for colder conditions, since it shows high heat resistance and good moisture management. The material sample 3 is made of is not recommended for sports underwear production.

Sample 2 that has an interlock pique interlace and a good peeling grade is recommended for producing sportswear, and sample 3 is not recommended since it would be quickly pilling during use and maintenance.

Based on these results, a selection of materials for sportswear can be made for certain climatic conditions and a certain degree of wearer activity.

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