A FUNCTIONAL WOVEN FABRIC WITH CONTROLLED FRICTION COEFFICIENTS PREVENTING BEDSORES

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Abstract

This article presents the design and manufacture of a double-layer woven fabric with different friction coefficients on the right and left sides of the fabric, and additional of the friction coefficient differentiated by direction of the fabric. Cotton and viscose yarns have been used as raw materials for the production of woven fabric, taking into account the future use of such a fabric for anti-bedsore sheets.

Key words:

anti-bedsore fabrics, double-layer woven fabric, sheets, friction coefficient, cotton yarn, viscose yarn

Introduction

A bedsore is a broad and deep loss of skin or mucous membranes as the result of insufficient tissue nutrition and long-lasting pressure impact on the blood vessels. Bedsores are a very significant financial problem considering their frequency of occurrence. The costs of bedsore treatment have reache the level of US$7 billion ($7x10^9$) per year in the United States, and about £420 million in Great Britain. The data from other countries indicates that bedsore occurrence has arisen in between 7% and 35% of hospitalised patients, and depends principally on the kind of hospital or health centre, the primary disease, and the age of the patient. The total costs sustained on treating all bedsores of the fifth degree are significantly higher than the costs borne on treating first-degree bedsores. All these statements indicate and emphasise the need for applying the best possible prophylactic methods.

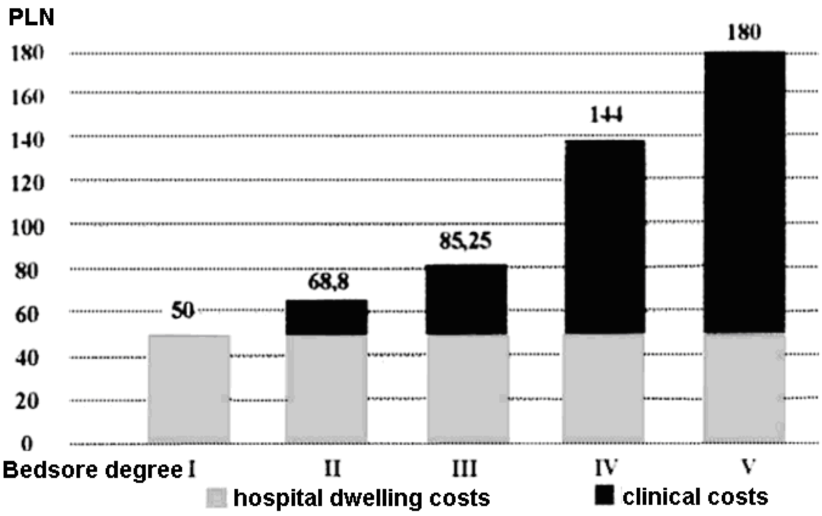


Figure 1. Estimated daily bedsore treatment costs in Poland

Many bedsore prophylactic and therapy methods exist. The use of ideally suitable bedclothes and undergarments for the patients are important elements of the prophylactic policy, independent of the use of special mattresses and anti-bedsore pillows, pharmacological and chemical products for skin care, and other means leading to prevent bedsore formation. These are the reasons why the textiles with which the patient has permanent and direct contact play an essential part in preventing bedsores. For example, standard hospital sheets are rough, which can lead to epidermis sores. Furthermore, the sheets absorb the moisture and heat released by the human body, and thus create an ideal environment for the growth of micro-organism. It seems that the functionality and therapeutic usability of textiles in the prevention of bedsores has not so far achieved a suitable standard, considering their importance. We expect the selection of appropriate design and textiles to significantly decrease the medical treatment costs, and improve the patients' physiological and sensorial comfort.

Physiological comfort, in the case of bedclothes and undergarments, results from the ability to absorb and transport moisture, whereas sensorial comfort is connected with the feeling of the touch of textiles on the skin. Physiological comfort also depends on a lack of thermal discomfort or the feeling of perspiration. From the above-mentioned considerations, we can conclude that the textiles used for patients' bedclothes and undergarments should be characterised by a smooth surfaceand good transmission of moisture and heat out from the patient's body.

A patient with bedsores requires permanent nursing, including repeated changes of the body position, the replacement of dressings, undergarments and bedclothes. The friction of the human body on textiles, generally connected with irritation of the epidermis by the rough woven fabric surface (which is often additionally covered with pilling), causes the beginning of bedsore wounds, or worsening those which already exist.

The anti-bedsore sheet

The hospital sheet plays an especially important role in the prophylactic and medical treatment of bedsores. Independent of its part in preventing bedsores, the sheet should also make the nursing of the patient easier by aiding the maintenance of the patient's body position , and at the same time enabling an easy change of this position by those persons who have the patient under care. This inconsistency is apparent, as it is possible to design textile products which have friction coefficients directionally differentiated and programmed in the direction of weft, warp, or even in both these directions. Independent of ensuring physiological comfort, the right side of the sheet should have a greater friction coefficient along the bed's direction (stabilisation of the patient's position) and a significantly smaller friction coefficient in the transversal direction (ease of transversal dislocation, and in rotating the patient). At the same time, the left side of the sheet should have a surface which makes the displacement of the sheet on the mattress or other underlay impossible. Such a sheet design prevents the sheet from becoming wrinkled, and prevents the formation of tucks, which thanks to the formation of sharp unevennesses are conductive to epidermis abrasions.

Traditional cotton and cotton-like sheets and pyjamas ensure physiological comfort, but can also be one of the causes of bedsore formation. Thus, a special anti-bedsore sheet should have the construction of an assembly (packet) with distinctly differentiated right and left sides. The right side of such a woven fabric should be manufactured by a weave which guarantees a smooth surface with distinctly differentiated friction coefficients in the longitudinal and transversal directions. The left side should have a relief character, and thus be rough and adhesive to the underlay.

Guidelines for sheet design

We accepted the following design guidelines:

- The right side of the woven fabric should have a smooth and slippery surface; good hygroscopicity and water retention; a 'friendly' touch (feeling of freshness); softness; a friction coefficient greater along the warp than along the weft.
- The left side of the woven fabric should have a rough surface (high friction coefficient along warp and weft); good adhesion to the underlay; good hygroscopicity and water retention (the water retention values for selected fibres are listed in Table 1).

Cotton and viscose fibres were chosen as raw material, considering their physical and mechanical properties and their generally accepted maintenance procedure. The standard woven fabric destined for bedclothes was chosen as the basic construction of the woven fabric we designed. Selected fabric parameters are shown in Table 2. Antibacterial viscose should be applied in the final construction of the sheet fabric, with the aim of limiting the development of micro-organisms.

Table 1. Water retention of selected fibres

No.	Kind of fibre	Value of water retention (%)
1	PA 6	9-11
2	PA 66	9-11
3	PU Laycra	7-11
4	PES – standard	0
5	PP	0
6	PAN	5-12
7	PAN – Dunova	40-60
8	Viscose	85-120
9	Cotton	45-50
10	Wool	40-45
11	Natural silk	45-50

Table 2. Parameters of the woven fabrics considered for designing the sheet

Parameter		Warp	Weft
Raw material	Upper layer	Cotton	Viscose
	Bottom layer	Cotton	Cotton
Linear density	Upper layer	40 tex	15 tex x 3
	Bottom layer	40 tex	40 tex
Density	Upper layer	220 threads/dm	220 threads/dm
	Bottom layer	220 threads/dm	220 threads /dm

The viscose weft threads applied in the upper layer have a smooth, irregularity-free surface which is characteristic of these fibres. High hygroscopicity and good water retention are their additional advantages. This creates an appropriate microclimate in the layer positioned immediately near the patient's skin. The moisture transmitted from the body does not cause the common unfavourable feeling of discomfort, which results in a decrease of the frequency with which the bedclothes are changed. The cotton threads, independent of their high hygroscopicity and good water retention, are characterised by surface roughness and irregularity, which features justify their being applied when manufacturing the sheet's left side.

The weft sateen weave was chosen for the upper layer of the woven fabric, whereas the honeycomb weave was chosen for the bottom layer. Both layers of the woven fabric were joined by the method of overbonds, with two overbond points per report. The weaves of the woven fabric have been designed as described above, in order to fulfil the guidelines mentioned above.

The long, non-interlaced segments of the viscose weft in the sateen weave of the upper layer (the right side of the sheet) ensure the feeling of softness and pleasant touch. The magnitude of the report, and at the same the length of the resulting interlaces, were chosen experimentally by the trial-and-error method with the criterion of avoiding excessive thread shifting in the woven fabric. The classical honeycomb weave applied for the left woven fabric's side formed a surface profile characterised by great roughness and good adhesion to the underlay. In addition, the honeycomb weave is characterised by the appearance of concavities and convexities on the fabric's surface, which form a geometrical relief on the woven fabric surface; this relief facilitates the micro-ventilation of the assembly.

The weaves of the upper and the bottom layers, together with a scheme of the complex woven fabric's weave, are presented in Figure 2, and a model of such a product is shown in Figure 3.

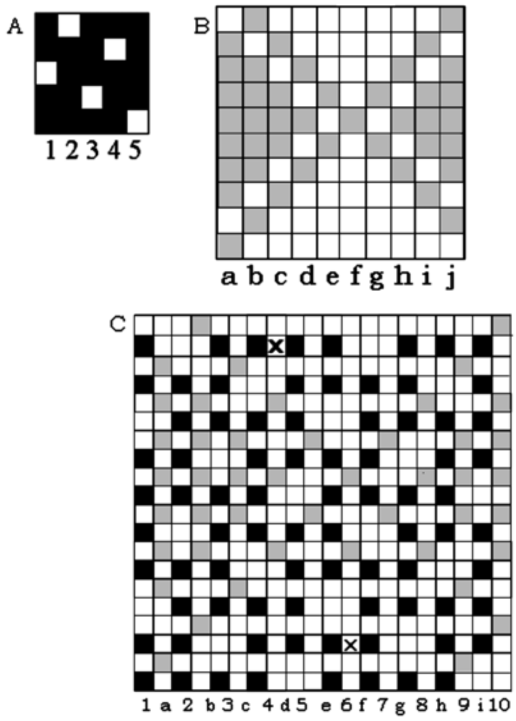
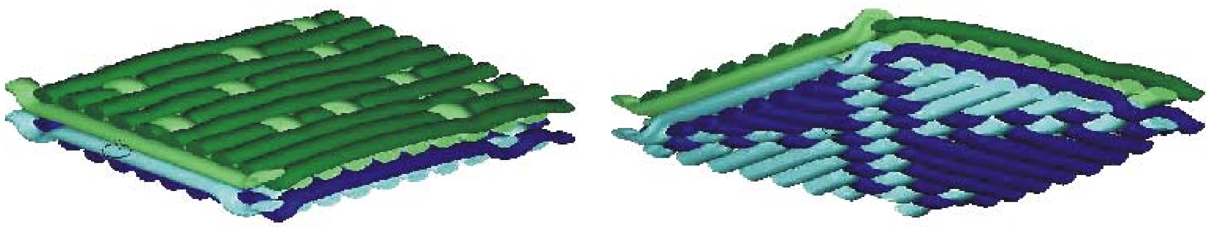


Figure 2. Weaves of a sheet woven fabric; A – weave of the upper layer: sateen weave 4-1 (3); B – weave of the bottom layer: 10-thread honeycomb weave; C – weave report of the complex woven fabric; X – overbond points.



A **B**

Figure 3. Model of the functional woven fabric; A – right side of the fabric, B – left side of the fabric; designed by WiseTex software

Double-layer woven fabric manufacturing and testing

The woven fabric we designed was manufactured with the use of a laboratory TC-1 loom from the Digital Weaving Norway AS company, equipped with two warp beams. The warp and weft densities were selected within the range of the woven fabrics commonly used for bedclothes.

With the aim of estimating the influence of the fabric construction on its tribological properties, we carried out specially programmed metrological tests. The friction coefficient was tested in relation to the products which are in direct contact with the sheet.

Typical textile products used for the production of the patient's underclothes were applied as abrasive material for testing the right side of the sheet woven fabric manufactured from viscose and cotton threads. The following products were selected:

- knitted fabric of plain stitch, designated as 'a' – raw material: cotton, linear density: 18 tex; wale density: 200 loops/dm; course density: 200 loops/dm;

- woven fabric of sateen weave, designated as 'b' – raw material: polyester; warp linear density: 15 tex; weft linear density: 16 tex; warp density: 320 threads/dm; weft density: 520 threads/dm;
- flannelette woven fabric, designated as 'c' – raw material: cotton; warp linear density: 50 tex; weft linear density: 83 tex; warp density: 200 threads/dm; weft density: 140 threads/dm.

Typical textile products used for the production of the sheet's underlays, such as mattresses and hospital protective covers, were applied as abrasive material for testing the left side of the sheet woven fabric.

The following products were selected:

- woven fabric with plain weave, designated as 'd' – raw material: cotton; warp linear density: 60 tex; weft linear density: 80 tex; warp density: 150 threads/dm; weft density: 270 threads/dm;
- velvet woven fabric, designated as 'e' – raw material: polyester; warp linear density: 24 tex; weft linear density: 24 tex; warp density: 200 threads/dm; weft density: 340 threads/dm;
- rehabilitation protective cover of the Bi-Elastic type with a two-layer structure, designated as 'f' – (a knitting fabric coated with medical-quality polyurethane).

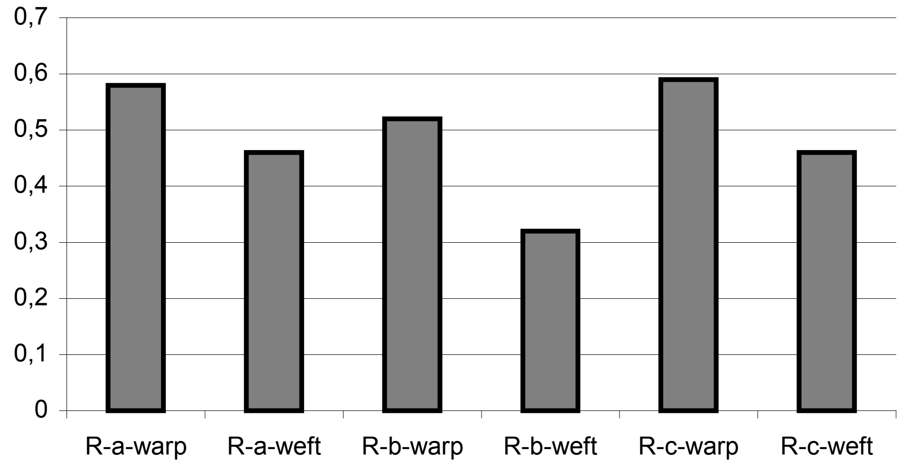


Figure 4. Average values of the friction coefficient between the right side of the woven fabric and the abrasive materials tested in warp and weft directions

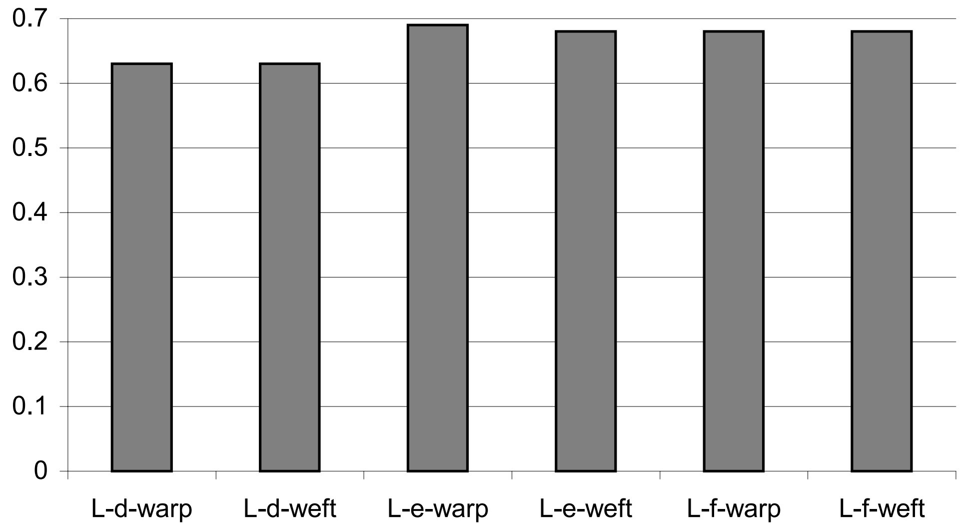


Figure 5. Average values of the friction coefficient between the left side of the woven fabric and the abrasive materials tested in warp and weft directions

The friction coefficient tests were carried out with the use of a device working on the basis of the inclined plane. Thus, the friction coefficient was determined as the tangent of the inclination angle of

the plane covered with the woven fabric tested, upon which a carriage covered with one of the abrasive materials began to slide down. A steel rectangular prism with a unit pressure (load) of 20 cN/cm^2 was used as the carriage. The samples of the particular products tested were connected in pairs with the preservation of the rule of arrangement of the surfaces in contact as described below. The right side of the sheet woven fabric was connected with the pyjama products described above, and designated as 'a', 'b', and 'c'; the left side of the sheet woven fabric was connected with mattresses and hospital protective covers designated as 'd', 'e', and 'f'. The products applied as abrasive materials, which had a directional structure, were positioned on the carriage diagonal at an angle of 45^0. Twenty measurements along the warp and the weft of the sheet woven fabric were carried out for each pair of materials. The test results are presented in Figures 4 and 5.
The results of the analysis of the statistical significance of the differences between the friction coefficient values are presented in Table 3.

Table 3. Statistical significance of differences between the friction coefficient values

Compared variants	Significance of differences
1	*2*
R-a- warp and R-a-weft	+ (C_0=23,39; $C_{0.05}$=18.40)
R-b- warp and R-b-weft	+ (t_0=190; $t_{0.05}$=2.093)
R-c- warp and R-c-weft	+ (C_0=339; $C_{0.05}$=18.33)

C – statistic of the Cox test, t – statistic of the t-Student distribution

Summary

The tests carried out allowed us to state that significant differences were achieved between the values of the friction coefficients in the warp and the weft directions for the right side of the sheet woven fabric. In accordance with our assumptions, the friction coefficient of the woven fabric was higher in the warp direction than in the weft direction, which was true for all the abrasive materials used. For the low friction coefficient in the warp direction, the used and the smooth weft threads which formed the fabric surface were decisive. On the other hand, the honeycomb weave of the left fabric's side was the cause for the friction coefficient being higher than for the right side and for its having equal values in the warp and weft directions.

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