

# ENSURING THE FUNCTIONALITY REQUIREMENTS OF THE TEXTILE PRODUCTS THAT ARE DESIGNED FOR PROTECTION, SAFE AND HEALTH

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**REZUMAT:** Cercetările prezentate în cadrul acestui proiect vizează identificarea și aplicarea unor soluții tehnico-constructive și tehnologice care au ca rezultat proiectarea și fabricarea unei game de produse textile obținute prin tricotare. Aceste produse au fost concepute special pentru a satisface cerințele superioare în ceea ce privește protecția, siguranța și menținerea sănătății purtătorului. Grupul de clienți vizați cuprinde persoane expuse accidentelor în timp ce își desfășoară activitatea, sportivi profesioniști și animatori și persoane care practică activități de petrecere a timpului liber.

**Cuvinte cheie:** produse textile tricotate, sănătate, protecție, securitate, design, inovație tehnologică

**ABSTRACT:** The research presented within this project aims at identifying and applying some technical-constructive and technological solutions which result in designing and manufacturing a range of textile products obtained through knitting. These products were specially designed in order to meet and ensure superior requirements regarding the protection, safety, and health maintenance of the wearer. The targeted group of clients comprises people exposed to accidents while doing their jobs, professional athletes and entertainers, and people who practice leisure activities.

**Keywords:** knitted textile products, health, protection, security, design, technological innovation.

## 1. INTRODUCTION

In the fields of research and industry, great attention is paid to the development of products belonging to the category of technical textiles and intelligent textiles, which are remarkably demanded on the market. One of the trends is to develop new types of garment that would ensure the wearer's protection, safety and health. These are customised intelligent products with a higher degree of functionality and with superior comfort and aesthetic properties, which are client/wearer-oriented.

This trend is roughly concerned with:

- Developing new textile products for an improved human performance;
- Customised intelligent products that are multifunctional;
- Products that ensure protection, safety and health preservation;
- Intertwining aesthetical elements and functional/technical features;

- Applying new design concepts;
- Creating, developing and manufacturing the above mentioned products.

While practicing various professions, sports or leisure activities, people can be exposed to extreme environmental conditions, to accidents, as well as to occupational health hazards or the aggravation of already existing illnesses [1], [2].

The textile products presented in this paper have the following general properties:

- An overall diversification of the technological processes when manufacturing advanced textile products;
- The development of textile technologies by creating a range of state-of-the-art machines which would enable the manufacturing of new types and shapes of textile products;
- The use of innovative raw materials, yarns and textile surfaces, apart from the traditional ones, with new properties and structures, which would allow the satisfaction of a wide range of destinations with specific

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functionalities (in our case, yarns with elastic and thermal properties, with increased mechanical stress endurance).

The changes which have taken place in the textile field were determined by: the wearer's need for comfort and performance, the advanced technologies that influence the innovative production processes, the need to meet higher standards of safety, health and aesthetics, and ecological ethics. All of the above have led to a steady diversification of the offer and, as a consequence, of the technical or intelligent textile market. [1].

From the multitude of factors which influence in a negative way the health or work ability of people, an essential role is played by the physiological and ergonomic factors that can lead to the occurrence of the following illnesses:

- ✓ Bone, muscles and joints disorders, as well as connective tissue illnesses;
- ✓ Synovitis and tenosynovitis, bursitis, epicondylitis, generated by: repetitive behaviour, unnatural joint positions, strain and long-term stress on joints, extreme tension applied on joints and joint trauma;
- ✓ Chronic arthritis, peri-arthritis, generated by: repetitive behaviour, unnatural and forced positions of joints, strain and long-term stress on joints, extreme tension or trauma applied on joints, vibrations, and unfavourable work environment;
- ✓ Occupational illnesses caused by exposure to physical agents;
- ✓ Thermal shock and collapse;
- ✓ Hypothermia and frostbite;
- ✓ Illnesses caused by vibrations: bones, muscles and joints syndromes, digestive syndrome, and nervous system syndrome

The textile products which are presented in this paper target people with a high risk of accidents or who can develop various occupational or non-occupational illnesses, determined by the following factors:

- Repetitive movements
- Excessive strain on joints and joints trauma;
- Excessive use of joints and long-term pressure on joints;
- Unfavourable microclimate.

The above mentioned groups of people are represented by:

- Professional athletes ;
- People who do exercise occasionally, for entertainment purposes;
- People who practice various activities in their leisure time.

The paper studies thoroughly the manufacturing of certain textile products with specific functionality, aiming at ensuring protection and safety during

various professional or entertaining activities. The focus is on the limbs because they are exposed to the previously mentioned illnesses.

## 2. TEXTILE PRODUCTS DESIGNED TO PROVIDE PROTECTION AND SAFETY DURING PROFESSIONAL, ENTERTAINING OR SPORTS ACTIVITIES

Functional textiles which aim to prevent, improve or provide post-surgery recovery for the illnesses mentioned in the previous paragraph are usually obtained through knitting by intertwining yarns with different properties and jersey with various structures and forms, choosing the fabrics that are suitable for the end user. In the case of some medical products such as orthotic devices for limbs, their basic functions are those of support and compression. The compression level is adjusted depending on the wearer's anatomy and on the doctor's recommendations in what concerns the illness. The compression values are obtained by adjusting the values of the technological parameters that define the knitting process [3]. For example, if we consider a product designed for the lower limbs, the degree of compression gradually decreases from the lower to the upper level; thus, the biggest compression rate occurs at the ankles, diminishing until it reaches the hips.

Generally, depending on their destination, the knitted products must have a range of properties that depend on raw material properties, on their structure and their structural parameters. A precise knowledge of the factors which influence various properties and of the interconnection among these properties allows a judicious functional and technological design of knitted products, through precise calculation.

Functional design aims at establishing the shape of the knitted products as well as the structural parameters for different areas of the finished garment, by taking into account the physical, mechanical, and hygiene functional properties of the product, according to its use. [4].

The products on which we focused in our researches comprise articles for lower limbs such as foot bottoms, socks, and legwarmers.

The research was carried out throughout several stages:

- The design and knitting of the initial products;
- Testing the products and analysing them so as to establish their capacity to meet the requirements imposed by their destination;
- The optimization of these products by redesigning them;

- Manufacturing new products based on the results obtained after the optimisation of the initial garments.

### 3. TECHNICAL-CONSTRUCTIVE AND TECHNOLOGICAL SOLUTIONS FOR MANUFACTURING THE DESIGNED PRODUCTS

The technical, constructive and technological solutions applied in order to obtain knitted functional models are concerned with the functional and comfort requirements that are specific to the product's field of use.

In order to establish the technological process, we decided upon the type of technology we were going to use, the nature of the engineered yarn, and the properties, shape and structure of the knitted textile apparels / products. Hence, two technological processes of manufacturing resulted:

- ❖ Technological process for obtaining knitted products by using dyed yarns
- ❖ Technological process for obtaining knitted products by using raw yarns.

The following knitted textile products were manufactured: 8 knitted functional models made of dyed yarns and 2 functional models made of raw yarns [5].

To obtain knitted products we used small circular knitting machines which allow the manufacturing of seamless products. The resulting textiles have a customised spatial form and ensure the functionality imposed by the destination.

The selected knitted machines are:

- SANGIACOMO-type small circular knitting machines with one knitting system, with a diameter of 4 ¾ and 144 needles, SANGIACOMO with one knitting system, a diameter of 4 ¾ and 168 needles, and Lonati GL 616H, with one knitting system, a diameter of 4 ¾, 200 needles, with an automatic system of toe closing, endowed with positive feeder systems and a programming software for designing and obtaining functional products;
- PENDOLINA small circular machines used for knitting medical socks / orthotic products, with the cylinder diameter of 4" ½, 4 working systems and 369 needles.

The following work parameters were taken into account when creating the knitted textile products – functional models:

- The core evolution – the plated jersey structure;

- The end-to-end knitting of the rows of stitches in the tubular (uncontrolled) areas of the products
- Alternative knitting of the rows of stitches in the spatial form areas, using yarns of different fineness and origins;
- The use of some combinations of knitted structures within the product.

By considering the specific method of obtaining the products, it is imperative to repeatedly modify them along their length and change their stitch length, therefore transforming the width of the stitch.

An important role in manufacturing the new products was played by the additional yarns, especially the elastic ones (elastomeric and silicone). These yarns, with a high elongation and a fast, almost complete rebound from deformation, offer remarkable functional and comfort performances to the knitted products, which can be adapted to various destinations

In the following paragraph we will briefly present the defining elements for obtaining technical-constructive and technological solutions when redesigning and manufacturing, respectively, new products based on the obtained results after optimising the initial products by using dyed and raw yarns. These products are as follows:

- Products for the lower limb, made of dyed yarns:
  - Redesigned foot bottom products: SV3R.1, SV3R.2
  - Redesigned/new sock-type products: SV5R.1, SV5R.2 / SV6.1, SV6.2
  - Redesigned/new legwarmer-type products: SV4L.R / SV5L.1, SV5L.2
- Orthotic products for the upper limbs:
  - with dyed yarns: OV3B-Rv, OV4D-Rv
  - with raw yarns: OV3B-Rc, OV4D-Rc.

Within our paper, the exemplification is made for the sock-type products SV5R.2, SV6.1, as well as for a legwarmer-type product SV4L.R, made of dyed yarns (Table 1).

For all the knitted structures included in our products we conducted tests by using the LRX Plus machine (Lloyd Instruments - Ametek – England). In order to be tested, every knitted product underwent the following stages: pre-tensioning using an initial force of 2N, applying stress throughout 5 cycles in order to reach a force of 10N. With the help of the NEXIGEN software, several types of graphs were drawn up for each test. Also, we have established a programme of calculating the hysteresis loops that are noticed on the force-lift graphs of the machine. This parameter highlights the quantity of energy absorbed by the material, an indicator for the future behaviour of the garment in what concerns elasticity, deformability and durability in time. [5].

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*Table 1. Functional models for the lower limb, made of dyed yarns*

| Functional model/codification  | Technical-constructive and technological characteristics   |
|--|--|
| <p data-bbox="264 315 496 342">Sock SV5R.2(redesign)</p>  <p data-bbox="293 835 467 862">Sock SV6.1(new)</p>  | <ul style="list-style-type: none"> <li data-bbox="571 315 1374 371">➤ Equipment: small circular knitting machine for socks SANGIACOMO, D=3 ¾”, Na=144, 1 system</li> <li data-bbox="571 416 1374 472">➤ It was designed with the help of a software which was specifically made for knitting machines</li> <li data-bbox="571 517 1374 801">➤ Product: <ul style="list-style-type: none"> <li data-bbox="619 551 1023 577">- Tubular-type socks with spatial form</li> <li data-bbox="619 584 1374 640">- The sequentially-knitted parts of the products are: the welt, the leg, the heel, the instep and the toe</li> <li data-bbox="619 647 1374 703">- The welt, the leg, and the instep were obtained by using a circular knitting system</li> <li data-bbox="619 710 1241 736">- The heel and the toe were knitted through pendular rotation</li> <li data-bbox="619 743 1374 799">- The used structures are: plated jersey for the welt, leg, instep, and plus fabric for the heel, sole and toe.</li> </ul> </li> <li data-bbox="571 844 1374 1391">➤ Raw materials: <ul style="list-style-type: none"> <li data-bbox="619 878 863 904">- We used dyed yarns</li> <li data-bbox="619 911 1374 967">- The core yarn of the welt and leg is resistant to damage (friction and cutting)</li> <li data-bbox="619 974 1374 1030">- The core yarn from the heel, instep and toe ensures comfort when wearing the product</li> <li data-bbox="619 1037 1374 1198">- Sock SV5R.2 <ul style="list-style-type: none"> <li data-bbox="683 1070 1374 1126">○ The basic yarn for welt and leg is a mixture with F1 fineness, and for the other areas a bamboo-based yarn was used.</li> <li data-bbox="683 1133 1374 1189">○ The additional yarn with elastic properties used for welt and leg has F3 fineness and for the other areas was used an F4 yarn.</li> </ul> </li> <li data-bbox="619 1205 1374 1391">- Sock SV6.1 <ul style="list-style-type: none"> <li data-bbox="683 1238 1374 1294">○ The core yarn for welt and leg is mixed and has F2 fineness; for the other areas, a cotton yarn was used.</li> <li data-bbox="683 1301 1374 1391">○ The additional yarn with elastic features used for obtaining the welt and the leg is a F3 fineness yarn; for the other areas we used a F4 fineness yarn.</li> </ul> </li> </ul> </li> </ul> |
| <p data-bbox="220 1406 523 1433">Legwarmer SV4L.R (redesign)</p>    | <ul style="list-style-type: none"> <li data-bbox="571 1406 1374 1462">➤ Equipment: SANGIACOMO small circular knitting machine for socks, D=3 ¾”, Na=168, 1 system</li> <li data-bbox="571 1507 1374 1563">➤ The design was accomplished by using a software specially made for knitting machines</li> <li data-bbox="571 1570 1374 1765">➤ Product: <ul style="list-style-type: none"> <li data-bbox="619 1603 943 1630">- tubular-type knitted garment</li> <li data-bbox="619 1637 1278 1664">- The parts of the product are: elastic top, leg 1, leg 2, lower welt</li> <li data-bbox="619 1671 1315 1697">- The entire product was obtained by using a circular knitting system</li> <li data-bbox="619 1704 1102 1731">- The lower welt was doubled through knitting</li> <li data-bbox="619 1738 1166 1765">- The structure used for all the parts was plated jersey</li> </ul> </li> <li data-bbox="571 1809 1374 1998">➤ Raw materials: <ul style="list-style-type: none"> <li data-bbox="619 1843 863 1870">- We used dyed yarns</li> <li data-bbox="619 1877 1374 1933">- The core yarn that was used for the entire product is resistant to friction and cutting, as it is a mixed yarn with F1 fineness</li> <li data-bbox="619 1939 1374 1998">- The additional yarn has elastic properties with F3 fineness for the elastic top, lower welt and leg 2, and F4 fineness, respectively, for leg 2.</li> </ul> </li> </ul>  |

## 4. CONCLUSIONS

Because it is necessary to prevent accidents, the occurrence of occupational illness or the aggravation of already existing illnesses during work, sports or leisure activities, functional textiles with pre-established destination were created by relying on the knitting technology.

The identification of technical-constructive and technological solutions for satisfying the wearer's requirements has led to the manufacturing of a range of knitted products that are optimal for certain parts of the human body (upper and lower limbs).

The identified solutions and the concrete manufacturing of the desired functional products are included in a research contract [5].

The elements which led to the creation of some customized functional products, focusing on technical-constructive and technological properties, were established by considering the following:

- The method of choosing raw materials – different types of yarns for knitting endowed with specific features due to their composition, fineness and origin, as well as their placement in the product;
- The geometry of the knitted product;
- Structures embedded in distinct areas of the product;
- The choice of machines which would meet the requirements for manufacturing garments with specific properties according to their destination; they must also meet ergonomic and comfort requirements.

In this paper we present the results of the research that focused on the knitting of products for the lower limbs (socks, legwarmers).

By assessing the designed, redesigned and manufactured products, we notice the following aspects:

- The selection of the raw materials which had the most suitable behaviour during the knitting process and while testing the products;
- The choice of the most suitable arrangement of the parts of the product in what concerns limb geometry, fabric behaviour when worn and expected guided protection;
- The identification of the best structures for various areas of the product in correlation with an adequate adjustment of the technological parameters in order to ensure the product's compactness, stress and strain endurance, dimensional stability, as well as comfort;
- An appropriate selection of the knitting machines which use specific software that allows the design and accomplishment of adequate shapes and structures within the products.

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